PHILOSOPHICAL TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCXCVI.

PART II.

LONDON,

SOLD BY PETER ELMSLY,
PRINTER TO THE ROYAL SOCIETY.
MDCCXCVI.

CONTENTS.

XI. *Of the Influence of Cold upon the Health of the Inhabitants of* London. *By* William Heberden, *Jun. M. D. F. R. S.* p. 279

XII. *An Analysis of the* Carinthian *Molybdate of Lead; with Experiments on the Molybdic Acid. To which are added some Experiments and Observations on the Decomposition of the Sulphate of Ammoniac. By* Charles Hatchett, *Esq. Communicated by Sir* Joseph Banks, *Bart. K. B. P. R. S.* p. 285

XIII. *Observations of the diurnal Variation of the Magnetic Needle at Fort* Marlborough, *in the Island of* Sumatra. *By* John Macdonald, *Esq. In a Letter to* John Crisp, *Esq. F. R. S.* p. 340

XIV. *Particulars of the Discovery of some very singular Balls of Stone, found in the Works of the* Huddersfield *Canal. By Mr.* Benjamin Outram, *Engineer to the* Huddersfield *Canal Company. Communicated by Sir* Joseph Banks, *Bart. K. B. P. R. S.* p. 350

XV. *Account of the Earthquake felt in various Parts of* England, *November* 18, 1795; *with some Observations thereon. By* Edward Whitaker Gray, *M. D. F. R. S.* p. 353

XVI. Newton's *Binomial Theorem legally demonstrated by Algebra. By the Rev.* William Sewell, *A. M. Communicated by Sir* Joseph Banks, *Bart. K. B. P. R. S.* p. 382

XVII. *A Description of the Anatomy of the Sea Otter, from a Dissection made November 15th, 1795, by* Everard Home, *Esq. F. R. S. and Mr.* Archibald Menzies. *Communicated by* Everard Home, *Esq.* p. 385

XVIII. *Observations on some ancient metallic Arms and Utensils; with Experiments to determine their Composition. By* George Pearson, *M. D. F. R. S.* p. 395

XIX. *On the periodical Star α Herculis; with Remarks tending to establish the rotatory Motion of the Stars on their Axes. To which is added a Second Catalogue of the comparative Brightness of the Stars. By* William Herschel, *LL.D. F. R. S.* p. 452

XX. *Abstract of a Register of the Barometer, Thermometer, and Rain, at* Lyndon, *in* Rutland, 1795. *By* Thomas Barker, *Esq. Communicated by* Thomas White, *Esq. F. R. S.* p. 483

XXI. *Observations on the Changes which Blood undergoes, when extravasated into the urinary Bladder, and retained for some Time in that Viscus, mixed with the Urine. By* Everard Home, *Esq. F. R. S.* p. 486

XXII. *On the Fructification of the submersed Algæ. By Mr.* Corrêa de Serra, *F. R. S.* p. 494

Presents received by the Royal Society, *from* November, 1795, *to* June, 1796 p. 507

Index. p. 511

PHILOSOPHICAL TRANSACTIONS.

XI. *Of the Influence of Cold upon the Health of the Inhabitants of* London. *By* William Heberden *Jun. M. D. F. R. S.*

Read March 10, 1796.

THE extraordinary mildness of last January, compared with the unusual severity of the January preceding, affords a peculiarly favourable opportunity of observing the effect of each of these seasons contrasted with each other. For of these two successive winters, one has been the coldest, and the other the warmest, of which any regular account has ever been kept in this country. Nor is this by any means an idle speculation, or matter of mere curiosity; for one of the first steps towards preserving the health of our fellow-creatures, is to point out the sources from which diseases are to be apprehended. And what may make the present inquiry more particularly useful, is that the result, as I hope clearly to make appear by the following statements, is entirely contrary to the prejudices usually entertained upon this subject.

During last January, nothing was more common than to hear expressions of the unseasonableness of the weather; and fears lest the want of the usual degree of cold, should be productive of putrid diseases, and I know not what other causes of mortality. On the other hand, "a bracing cold," and "a clear frost," are familiar in the mouth of every Englishman; and what he is taught to wish for, as among the greatest promoters of health and vigour.

Whatever deference be due to received opinions, it appears to me however from the strongest evidence, that the prejudices of the world are upon this point at least unfounded. The average degrees of heat upon FAHRENHEIT's thermometer kept in London during the month of January 1795, was 25° in the morning, and 29°.4 in the afternoon. The average in January 1796, was 43°.5 in the morning, and 50°.1 in the afternoon. A difference of above twenty degrees! And if we turn our attention from the comparative coldness of these months, to the corresponding healthiness of each, collected from the weekly bills of mortality, we shall find the result no less remarkable. For in five weeks between the 31st of December 1794 and the 3d of February 1795, the whole number of burials amounted to 2823; and in an equal period of five weeks between the 30th of December 1795 and the 2d of February 1796, to 1471. So that the excess of the mortality in January 1795 above that of January 1796, was not less than of 1352 persons. A number sufficient surely to awaken the attention of the most prejudiced admirers of a frosty winter. And though I have only stated the evidence of two years, the same conclusion may universally be drawn; as I have learned from a careful examination of the weekly bills of mortality for

many years. These two seasons were chosen as being each of them very remarkable, and in immediate succession one to the other, and in every body's recollection.

It may not be impertinent to the objects of this Society, without entering too much into the province of medicine, to consider a little more particularly the several ways in which this effect may be supposed to be produced; and to point out some of the principal injuries which people are liable to sustain in their health from a severe frost. And one of the first things that must strike every mind engaged in this investigation, is its effect on old people. It is curious to observe among those who are said in the bills to die above 60 years of age, how regularly the tide of mortality follows the influence of this prevailing cause: so that a person used to such inquiries, may form no contemptible judgment of the severity of any of our winter months, merely by attending to this circumstance. Thus their number last January was not much above $\frac{1}{4}$th of what it had been in the same month the year before. The article of asthma, as might be expected, is prodigiously increased, and perhaps includes no inconsiderable part of the mortality of the aged. After these come apoplexies and palsies, fevers, consumptions, and dropsies. Under the two last of which are contained a large proportion of the chronical diseases of this country; all which seem to be hurried on to a premature termination. The whole will most readily be seen at one view in the following table.

1795.

Week ending	Mean heat. Morn.	Mean heat. Noon.	Whole No. of deaths.	Aged above 60.	Asthma.	Apoplexy and palsy.	Fever.	Consumption.	Dropsy.
6 Jan.	25°	29°	244	51	13	4	20	73	7
13 Jan.	26°	32°	532	139	26	13	49	158	20
20 Jan.	24°	30°	637	145	51	11	81	164	37
27 Jan.	19°	27°	543	143	64	11	42	157	17
3 Feb.	25°	37°	867	239	95	13	66	273	45
Result	23°	29°.4	2823	717	249	52	258	825	126

1796.

Week ending	Mean heat. Morn.	Mean heat. Noon.	Whole No. of deaths.	Aged above 60.	Asthma.	Apoplexy and palsy.	Fever.	Consumption.	Dropsy.
5 Jan.	40°	46°	300	35	5	7	34	79	13
12 Jan.	41°	49°	273	37	9	5	25	53	19
19 Jan.	48°	53°	313	29	2	4	29	77	11
26 Jan.	47°	52°	257	20	7	9	23	47	11
2 Feb.	41°	49°	328	32	6	6	23	86	16
Result	43°.5	50°.1	1471	153	29	31	134	342	70

Notwithstanding the plague, the remittent fever, the dysentery, and the scurvy, have so decreased, that their very name is almost unknown in London; yet there has, I know not how, arisen a prejudice concerning putrid diseases, which seems to have made people more and more apprehensive of them, as the danger has been growing less. It must in great measure be attributed to this, that the consumption of Peruvian bark

in this country has, within the last fifty years, increased from 14,000 to above 100,000 pounds annually. And the same cause has probably contributed, from a mistaken mode of reasoning, to prepossess people with the idea of the wholesomeness of a hard frost. But it has in another place* been very ably demonstrated that a long frost is eventually productive of the worst putrid fevers that are at this time known in London; and that heat does in fact prove a real preventive against that disease. And although this may be said to be a very remote effect of the cold, it is not therefore the less real in its influence upon the mortality of London. Accordingly a comparison of the numbers in the foregoing table will shew that very nearly twice as many persons died of fevers in January 1795, as did in the corresponding month of this year. I might go on to observe that the true scurvy was last year generated in the metropolis from the same causes extended to an unusual length. But these are by no means the only ways, nor indeed do they seem to be the principal ways, in which a frost operates to the destruction of great numbers of people. The poor, as they are worse protected from the weather, so are they of course the greatest sufferers by its inclemency. But every physician in London, and every apothecary, can add his testimony, that their business among all ranks of people never fails to increase, and to decrease, with the frost. For if there be any whose lungs are tender, any whose constitution has been impaired either by age, or by intemperance, or by disease; he will be very liable to have all his complaints increased, and all his infirmities aggravated by such a season. Nor must the young and active think themselves quite secure,

* Observations on the Jail Fever, by Dr. Hunter, Med. Trans. Vol. III.

or fancy their health will be confirmed by imprudently exposing themselves. The stoutest man may meet with impediments to his recovery from accidents otherwise inconsiderable; or may contract inflammations, or coughs, and lay the foundation of the severest ills. In a country where the prevailing complaints among all orders of people are colds, coughs, consumptions, and rheumatisms, no prudent man can surely suppose that unnecessary exposure to an inclement sky; that priding oneself upon going without any additional clothing in the severest winter; that inuring oneself to be hardy, at a time that demands our cherishing the firmest constitution lest it suffer; that braving the winds, and challenging the rudest efforts of the season, can ever be generally useful to Englishmen. But if generally, and upon the whole, it be inexpedient, then ought every one for himself to take care that he be not the sufferer. For many doctrines very importantly erroneous; many remedies either vain, or even noxious, are daily imposed upon the world for want of attention to this great truth; that it is from general effects only, and those founded upon extensive experience, that any maxim to which each individual may with confidence defer, can possibly be established.

XII. *An Analysis of the* Carinthian *Molybdate of Lead; with Experiments on the Molybdic Acid. To which are added some Experiments and Observations on the Decomposition of the Sulphate of Ammoniac. By* Charles Hatchett, *Esq. Communicated by Sir* Joseph Banks, *Bart. K.B. P.R.S.*

Read April 14, 1796.

§ I.

THE celebrated SCHEELE, in 1778, read before the Academy of Sciences at Stockholm an essay, in which he proved, by a series of ingenious experiments, that the mineral called *Molybdæna* was composed of sulphur, and a peculiar metallic substance, which, like arsenic and tungsten, was liable by superoxygenation to be converted into a metallic acid, which in its properties differed from any other that had been previously discovered.*

The experiments of M. PELLETIER,† Mr. ISLMANN,‡ and Mr. HIELM,§ confirmed the discovery of the Swedish chemist; but the existence of this metallic substance was only known to be in that mineral which SCHEELE had examined, as no vestige of it had as yet been discovered in other bodies ap-

* SCHEELE's Essays, translated by Dr. BEDDOES, p. 227.

† *Journ. de Physique, Decembre,* 1785.

‡ *Chemische Annalen von* CRELL, 1787, *et Journ. de Physique, Octobre,* 1788.

§ *Journ. de Physique, Mai,* 1789.

pertaining to the mineral kingdom. Mr. JACQUIN, in 1781 and 1786, gave to the public an account, from the Abbé WULFEN, of a yellow sparry lead ore, found at Villach in Carinthia;* and the Abbé WULFEN himself, in an elaborate work, written in the German language, and published in 1785, also described the abovementioned lead ore, together with some experiments which had been made on it.†

Nothing satisfactory, however, relative to its nature was exposed in these memoirs; and although the substance was indisputably proved to be an ore of lead, yet the mineralizing principle of it remained unknown.

In 1790, Mr. HEYER, of Brunswick, made some experiments on this ore, from which he inferred that it was composed of lead, combined with the tungstic acid;‡ and in the same year Mr. KLAPROTH communicated to Dr. CRELL a similar account, which he had received from Mr. SALZWEDEL, of Frankfort sur Mayne.§

This substance was therefore universally believed to be a tungstate of lead, till that excellent chemist Mr. KLAPROTH undertook to subject it to a farther examination; and as the experiments which I have made may be regarded as a continuation of those made by Mr. KLAPROTH, I think it necessary here to mention them.

* NICOLAI JOSEPHI JACQUIN *Miscellanea Austriaca*, Tom. II. p. 139; *et* N. J. JACQUIN *Collectanea*, Tom. I. p. 3.

This ore is also described in *Litbophyl. Bornianum*, Tom. I. p. 90; *et* Tom. II. p. 123.—KARSTEN *in Mus. Lesk.* Tom. II. p. 501.—WERNER's *Verzeicb.* Band, I. p. 128.—RAAB's *Catal.* Tome II. p. 379.—*Romé de l'Isle Cristal.* Tome III. p. 387.—WIDENMANN's *Handbuch der Mineralogie*, p. 864.

† XAVIER WULFENS *Abhandlung vom Kärntbnerischen Bleyspate. Wien*, 1785.

‡ *Chemische Annalen von* CRELL, 1790, p. 58.

§ Ibid. 1790, p. 297.

Mr. KLAPROTH says, that by previous experiments he had found, that nitric acid much diluted did not attack the ore when cold; and therefore to separate it from the soluble matrix, he successively poured small quantities of the diluted acid on the ore till all effervescence had ceased, after which the ore was washed and dried. The nitric acid which had been employed was found to contain calcareous earth, and also a considerable quantity of red oxyde of iron, which upon being dissolved in sulphuric acid, left a residuum of lead and siliceous earth.*

Two drachms of the purified ore were mixed with an equal quantity of pot-ash, and afterwards exposed to the fire in a crucible. The mixture melted without intumescence. When cold, the mass was of a reddish colour, and the surface was covered with small scales. Water was poured on it, and the solution was saturated with nitric acid. The following day, the bottom of the glass was found covered with projecting crystals, about a quarter of an inch in length: these crystals were formed of small glittering rhomboidal plates, heaped one on the other. Their flavour was rather metallic. They quickly melted with the blow-pipe, on charcoal, without any increase of bulk, and became small round drops, which were immediately absorbed by the charcoal. When melted by the blow-pipe in a silver spoon, they appeared as small grains, of a greyish colour, which became streaked in cooling, and deposited a white powder during the operation.

When the phosphate of ammoniac and soda was melted, and some of these crystals were added, they speedily dissolved,

* *Analyse Chimique du Plomb Spathique jaune de Carinthie. Annales de Chimie*, 1791, pag. 103.

and communicated to the salt a green colour, more or less deep according to the quantity employed.

They completely dissolved in distilled water, when heated.

Prussiate of pot-ash with this solution produced a reddish-brown precipitate, not very dark.

When some drops of muriatic acid were mixed with the solution of these crystals in water, and a small piece of tin was added, the liquor became of a deep blue.

The solution of muriate of tin poured on the crystals produced the same effect.

Mr. KLAPROTH from these experiments concludes, that the crystals are the acidulous molybdate of pot-ash, especially as the crystals obtained from the filtrated solution of the molybdæna of Altenberg, detonated with nitre, and saturated with nitric acid, have the same properties.

As in the above experiment the ore did not appear to have been completely decomposed, Mr. KLAPROTH mixed two drachms of the purified ore with ten of carbonate of pot-ash, melted the whole in a crucible, and reduced it to powder, and dissolved it in water.

The solution was filtrated, partially saturated with muriatic acid, and heated. A white precipitate fell, resembling curdled milk, which consisted of molybdic acid, and a still larger quantity of oxyde of lead. When dissolved in muriatic acid, the lead was precipitated in the state of muriate of lead.

This precipitate being separated by a filter from the alkaline solution partially saturated with muriatic acid, the solution was then completely saturated with the same acid, and again became slightly turbid, and deposited a white precipitate, which resembled starch in cold water. This precipitate,

after it had been washed and dried, was subjected to the same experiments as the abovementioned crystals, and exhibited the same properties, excepting that it did not dissolve in distilled water till some drops of muriatic acid were added.

When the solution was evaporated in a glass bason, the rest of the oxyde of molybdæna was deposited in the form of a heavy citron-coloured powder.

The white oxyde of lead on the filter through which the solution of the alkaline mass had passed, was found to be mixed with siliceous earth. When melted on charcoal, it did not entirely assume the metallic form, but a part changed into a small grain of transparent yellowish vitrified oxyde of lead. Mr. KLAPROTH observes, that in this experiment the presence of the siliceous earth prevented the complete reduction of the lead, in the same manner as when glass of lead, composed of three parts of oxyde of lead and one of siliceous earth, is melted upon charcoal. He therefore dissolved this oxyde in weak nitric acid, separated the siliceous earth by a filter, and precipitated the lead by sulphuric acid.

Mr. KLAPROTH, however, doubts whether the greater part of the siliceous earth was not introduced, during the operation, by the action of the alkali on the crucible.

A drachm of the ore was digested with a considerable quantity of nitric acid, and a great part was dissolved. In the solution white flocculi were perceived, and were separated by a filter. When dried they were like a membrane, which became bluish when exposed to the light, and much resembled the molybdic acid obtained from molybdæna, by repeatedly distilling nitric acid from it. In the filtrated nitric solution there was much oxyde of molybdæna mixed with oxyde of

lead. The lead was therefore precipitated by sulphuric acid, and afterwards the molybdæna by prussiate of pot-ash.

A drachm of the ore was digested with muriatic acid, and was completely dissolved, excepting a small residuum of siliceous earth. The solution was transparent, and without colour. In the course of some time it plentifully deposited crystals of muriated lead. When these crystals were separated, the solution was evaporated, and the interior of the bason was, during the evaporation, covered with a bluish saline crust, which dissolved and the colour disappeared when the vessel was shaken. The concentrated solution decanted from the muriate of lead (which had been precipitated during the evaporation) was of a deep blue, which disappeared when water was added. The solution was then saturated with alkali, and deposited a white precipitate, which consisted of molybdic acid, together with a small quantity of oxyde of lead.

According to these experiments Mr. KLAPROTH remarks, that the yellow sparry lead ore of Carinthia is composed of oxyde of lead and molybdic acid, and that this mineralogical novelty is the more remarkable, as it is the only one of the kind known at present. It is also worthy of notice, that the molybdæna changes its form according to the method employed to precipitate it from alkaline solutions; for it is obtained either in a crystalline form, or in that of a white powder, or in that of a citron-coloured oxyde. When crystallized, it is soluble in acids, and in water; as a white powder it does not dissolve in water, unless a small quantity of muriatic acid is added; but in the state of the citron-coloured oxyde, it is insoluble in water as well as in the acids. Mr. KLAPROTH considers that this difference is occasioned by the presence of

some alkali in the two first substances, so as to form an imperfect neutral salt with the molybdic acid, but that the yellow powder is in the state of a simple oxyde.

This yellow colour probably occasioned the supposition that the lead was mineralized by the tungstic acid; but the blow-pipe is sufficient to distinguish them. The yellow oxyde of molybdæna loses the colour as soon as the point of the flame touches it, inclines to an olive colour, and melts into small grains, which are immediately absorbed by the charcoal. In the phosphate of ammoniac and soda it dissolves, and communicates to it a green colour. On the contrary, the yellow oxyde of tungsten by ignition becomes blue or black, remaining refractory, and with phosphate of ammoniac and soda it produces a sky-blue glass.

Mr. KLAPROTH concludes his paper by saying, that he could not exactly determine the proportions of the ingredients, as the quantity of the ore in his possession was not sufficient to make the necessary allowance for the solubility of the oxyde of lead in the alkalies, and especially that of the molybdic acid when in a state of combination.

These experiments of Mr. KLAPROTH certainly prove that this ore is a molybdate of lead; but as the quantity which he had was too small, either to make a greater number of experiments, or a regular analysis, I was induced to attempt a further investigation of it; and therefore in the course of the last summer I made the experiments and analysis which are described in this paper.

§ II. *Characters of the* Carinthian *Molybdate of Lead.*

The molybdate of lead is found at Villach, in Carinthia.* The matrix is a limestone, of a pale brownish-grey colour, often more or less tinged with oxyde of iron.

The ore is a heavy brittle substance, easily scratched with a knife, and of a yellow, varying from pale yellow to orange colour.

The fracture is sparry.

The external lustre is like that of wax, and when crystallized, two of the faces of the crystals are commonly opaque, and of a pale yellow, but the remaining four faces or sides have a resinous appearance.

It generally exhibits an appearance of crystallization, and the crystals, when perfect, afford various modifications between the octoëdral figure and the cube.

The specific gravity of a specimen, from which I had separated all the visible part of the matrix, was 5092 (the temperature of the water being 60°), but when the ore was reduced to powder, and purified by diluted nitric acid, I found the specific gravity to be 5706.

1. When the ore was examined by the blow-pipe, it at first split and crackled as soon as the point of the flame touched it, but afterwards readily melted into a dark coloured mass, in which were some shining globules of lead.

2. With borax it formed a brownish-yellow globule, but when it was in a small proportion, and heated by the interior

* It is said to have been sometimes found in Austria and Hungary, but I doubt if the nature of these ores is the same.

flame, it occasionally produced a glass, which was greenish blue, and sometimes deep blue.

3. With phosphate of ammoniac and soda it formed a sea-green glass, which in proportion to the quantity of the ore sometimes became deeper in colour, so as to be nearly of a deep blue.

Before I made the following experiments, I reduced eight ounces of the ore to a fine powder, and dissolved the matrix after the manner of Mr. KLAPROTH, by successively pouring on the powder small quantities of nitric acid diluted with six parts of distilled water, after which I edulcorated and dried the residuum. The nitric acid used in this operation contained (as Mr. KLAPROTH has mentioned) calcareous earth, oxyde of iron, and oxyde of lead; but as prussiate of pot-ash produced a pale green precipitate, I suspected that some other metallic substance beside iron and lead was in the solution. I therefore added muriate of tin to a portion of it, which was immediately changed from a pale yellow to a pale blue, and shewed that a small quantity of molybdic acid was present in the solution.

§ III. *Molybdate of Lead with Water.*

I boiled twelve ounces of distilled water on twenty grains of the purified ore in a glass matrass during three hours. The ore did not appear to be changed, nor did the water after it had passed the filter afford any trace of matter in solution. I believe, therefore, that the molybdate of lead is insoluble in water.

§ IV.

As Mr. KLAPROTH had proved the action of the fixed alkalies on the molybdate of lead, in the dry way, I was desirous to know what effects they would produce in the humid way, and therefore made the following experiments.

EXPERIMENT 1.

A. I boiled four ounces of strong lixivium of caustic pot-ash with twenty grains of the purified ore, till there remained at the bottom of the matrass a dry mass, which was partly red, yellow, and green. I reduced this to powder, and poured distilled water on it, till the water came away without any taste.

The alkaline solution was filtrated, and afterwards saturated with sulphuric acid. The liquor then became turbid, and deposited a small quantity of a white precipitate, which consisted of lead and some molybdic acid. This was separated by a filter, and prussiate of pot-ash being added to the clear liquor, precipitated a great quantity of molybdæna, in the state of a reddish-brown flocculent precipitate.

B. I took the residuum of the alkaline solution (which now was chiefly of a red colour, and appeared like minium) and poured nitric acid, very largely diluted, on it till the whole was dissolved. I then precipitated the lead with sulphuric acid, and from the clear liquor which remained I afterwards, by the means of prussiate of pot-ash, obtained a quantity of Prussian blue.

EXPERIMENT II.

A. Twenty grains of the purified ore were boiled with four ounces of a lixivium of carbonate of pot-ash. When all the water was evaporated, there remained a white saline mass, which was reduced to powder, and treated with distilled water as in the former experiment.

A large quantity of a heavy white residuum remained on the filter.

The clear solution was saturated as before with sulphuric acid, and a white precipitate, similar to that of the former experiment, was obtained. This was separated, and a copious precipitate of molybdæna was produced, upon the addition of prussiate of pot-ash.

B. The white residuum was then edulcorated, and when diluted nitric acid was poured on it, it was dissolved with effervescence. From this solution I precipitated the lead by sulphuric acid, and afterwards the iron by prussiate of pot-ash.

Ammoniac, when digested on the ore, had not any effect.

From these experiments it appears, that the molybdate of lead is decomposed by the fixed alkalies in the humid way, and that the component parts of the ore are lead and iron mineralized by the molybdic acid.*

* The alkalies, whether caustic or combined with carbonic acid, do not act in the humid way on molybdæna when mineralized by sulphur. Scheele's Essays, p. 230; and *Mémoire sur la Molybdène, par M.* Pelletier, *Journ. de Physique, Decembre*, 1785, p. 437.

§ V. *Molybdate of Lead with Sulphur.*

A mixture, composed of fifty grains of the ore and 150 grains of sulphur, was put into a small glass retort, to which a receiver was luted.

The fire was then gradually raised till all of the sulphur was driven over, and the bottom of the retort began to melt.

The residuum was a black loose powder, which was greasy to the touch, and soiled the fingers like molybdæna.

This black powder was digested in a strong heat with nitric acid, diluted with three parts of water.

Nitrous fumes were discharged during the digestion, and the powder was dissolved, excepting a residuum of molybdic acid, which was of a greenish-yellow colour.

The solution was diluted with an equal quantity of distilled water, and was filtrated. Sulphuric acid was then added till all of the lead was precipitated; after which I obtained a brown precipitate by prussiate of pot-ash.*

§ VI. *Molybdate of Lead with Carbonate of Ammoniac.*

A mixture, composed of 50 grains of the ore and 220 of dry carbonate of ammoniac, was put into a glass retort, and was sublimed with a gentle heat.

The molybdate of lead remained in the retort without having suffered any apparent alteration.

The ammoniac, however, had raised a small portion; for

* As the quantity of molybdic acid in the ore is much greater than that of iron, it is scarcely possible to discover the latter when they are precipitated together by prussiate of pot-ash.

when it was dissolved in distilled water, and was saturated with an acid, prussiate of pot-ash produced a brown cloud.

§ VII. *Molybdate of Lead sublimed with Muriate of Ammoniac.*

EXPERIMENT I.

A mixture of 50 grains of the molybdate of lead and 240 grains of muriate of ammoniac was sublimed.

The sublimate was partly yellow, green, and blue; there was also some muriatic acid, and the residuum was a black powder.*

A. The sublimate was mixed with an equal weight of sulphur, and distilled.

The residuum of this was a black powder, resembling the mineral called molybdæna, and when distilled with nitric acid, afforded a citron-coloured oxyde.

B. A quantity of distilled water was boiled on the residuum of the first sublimation, by which a part was dissolved, and communicated a blue colour to the water.

1. Prussiate of pot-ash added to some of this blue liquor, produced a precipitate of Prussian blue.

2. Sulphuric acid added to another portion deepened the blue colour.

3. Lixivium of carbonate of soda precipitated some ochry matter.

4. And nitrate of silver was decomposed, and muriate of silver was precipitated.

* M. Sage has observed, that molybdæna with muriate of ammoniac affords a blue sublimate. *Journ. de Physique*, 1788, p. 389.

C. Nitric acid diluted with six parts of water was then poured on the undissolved powder, and was digested on it in a sand heat.

The powder was nearly dissolved, and the solution was colourless.

1. From this solution I precipitated sulphate of lead by the means of sulphuric acid.

2. With prussiate of pot-ash I obtained a brown precipitate of molybdæna, and

3. Muriate of tin turned another portion of it blue.

From these experiments it appears that the first solution contained iron, with some molybdic acid dissolved in muriatic acid; and the second solution contained molybdic acid and lead.

Molybdate of Lead sublimed with Muriate of Ammoniac.

EXPERIMENT II.

125 Grains of the ore were mixed with two ounces of muriate of ammoniac, and put into an earthen matrass, to which a head of stone-ware was fitted. The matrass was then exposed to a sufficient degree of heat, and when all was sublimed the vessels were separated.

The black powder which remained was mixed with two ounces of muriate of ammoniac, and again sublimed.

This operation was repeated three times, after which nothing remained in the matrass. The sublimate, as before, was yellow, green, and blue.

A. Distilled water was poured on the sublimate, so as to

dissolve all of the saline part; but as the solution was turbid, it was poured on a filter, which collected a precipitate of a pale bluish-grey colour.

B. This precipitate after it had been edulcorated was boiled with distilled water, which was afterwards filtrated.

1. Prussiate of pot-ash precipitated some iron.

2. Muriatic acid was added to another portion, after which the prussiate produced a brown precipitate of molybdæna.

3. Muriate of silver was precipitated when nitrate of silver was dropped in.

C. I then boiled lixivium of carbonate of pot-ash on the undissolved part of the residuum, by which the greatest part was dissolved. The alkali was then saturated with muriatic acid, and prussiate of pot-ash being added, precipitated some molybdæna.

On the small portion of the residuum which remained I poured diluted nitric acid. The solution was then filtrated, and I obtained a small quantity of sulphate of lead by the means of sulphuric acid.

These experiments shew that the residuum was composed of molybdic acid, iron, lead, and a small quantity of muriatic acid, which was produced from the muriate of ammoniac during the sublimation.

D. I now took the solution A and divided it into two portions, to one of which I added three ounces of concentrated sulphuric acid, and evaporated the liquor to half of the quantity.

When it was cold it deposited a white saline matter, which for the greater part dissolved in water, leaving a small residuum which appeared to be muriate of lead.

Pot-ash expelled some ammoniac from a portion of the dry salt.

And a precipitate was produced when muriate of barytes was added to the solution. This white saline matter was therefore a mixture of sulphate of ammoniac with a small portion of muriate of lead.

The solution to which the sulphuric acid had been added was again evaporated to a considerable degree, and when cold it resembled a very thick mucilage of a pale yellow colour. It readily dissolved in water, and contained sulphuric acid in great excess.

1. Prussiate of pot-ash only changed the colour to pale green.

2. Carbonate of pot-ash expelled the ammoniac, and a white precipitate like starch was formed, which was principally composed of molybdic acid and pot-ash, on which I shall not make at present any observations, as it will be hereafter noticed in several parts of this paper.

It is worthy of notice, that prussiate of pot-ash did not precipitate the molybdæna from this mucilaginous salt, and that when the pot-ash expelled the ammoniac it formed with the molybdic acid a salt more difficultly soluble than that formed by ammoniac.

E. To the second portion of the solution I added three ounces of concentrated nitric acid, and evaporated it nearly to dryness.

A bright yellow matter was deposited, which I found to be molybdic acid combined with a portion of lead.

There was also a small quantity of liquid, which I diluted with distilled water, and then precipitated some sulphate of lead by sulphuric acid. When this was separated I added

prussiate of pot-ash, and obtained a quantity of Prussian blue.

§ VIII. *Molybdate of Lead, with black Flux.*

One hundred grains of the ore were mixed with four times the weight of black flux. The mixture was then put into a crucible with a piece of charcoal over it; a cover was fitted to the crucible, and it was placed in a furnace in which a strong heat was kept up during an hour. When the crucible was cold and was broken, there did not appear any reguline button, but shining metallic particles were dispersed throughout the mass.

It was then reduced to powder, and the largest particles were separated by washing, were dried upon paper, and weighed 31 grains; upon examination they proved to be lead in the metallic state.

Other particles were separated by a magnet, and the remainder consisted of a black powder.*

A. Diluted nitric acid was poured on this black powder and dissolved it, excepting a small residuum, which consisted of siliceous earth with a little charcoal.

1. The solution was diluted with distilled water and filtrated.

2. I then first separated a quantity of lead by sulphuric

* Scheele could not reduce molybdic acid by black flux. Scheele's Essays, p. 238.—Several chemists however assert, that they have obtained a regulus of molybdæna, particularly Mr. Hielm, in *Journ. de Physique*, 1789, p. 372.—And Mr. Ruprecht, *Journ. de Physique*, 1790, p. 231.—But Mr. Islmann did not succeed. *Journ. de Physique*, 1788, p. 296.

acid, and afterwards obtained some Prussian blue by prussiate of pot-ash.

B. The alkaline solution which had been formed when the melted mass was washed, was poured on a filter, and distilled water was added till it came away tasteless.

The filtrated liquor was without colour: nitric acid was then added till the alkali was saturated.

When about half of the requisite quantity of nitric acid was poured in, the liquor became pale blue, and as the quantity was increased it changed to green; and, lastly, when the nitric acid was added till it was in a small excess, the liquor was of a bright amber colour.

1. This solution, with prussiate of pot-ash, afforded a brown precipitate of molybdæna.

2. Muriate of tin changed the colour to a beautiful deep blue.

3. But sulphuric acid had not any effect.

C. The amber-coloured solution was evaporated to dryness, and a saline mass of a bright citron colour remained at the bottom of the vessel.

As part of the yellow colouring matter appeared to be only mixed with the salt, I dissolved it in distilled water, and separated a quantity of a citron-coloured powder, which was the molybdic acid.

The solution was twice again evaporated, and each time some molybdic acid was separated; but a part still remained intimately combined with the salt, so as with water always to produce the amber-coloured solution.*

* Although the solution at first afforded a brown precipitate with prussiate of pot-ash, yet when it had been twice evaporated, it required the addition of some nitric

I now proceeded to examine the ore with the acids.

As the results which I obtained when the ore was digested with nitric acid were the same as those mentioned by Mr. KLAPROTH, I shall not repeat them, but shall only observe, that it does not appear possible to decompose the ore completely by means of this acid.

§ IX. *Molybdate of Lead with Muriatic Acid.*

240 Grains of the purified ore in fine powder were put into a glass matrass, with three ounces of pure muriatic acid.

The matrass was then placed in a sand bath; in about an hour the whole was dissolved, excepting some muriate of lead, which I dissolved by pouring water on it.

After this there only remained a very small residuum of siliceous earth.

A. The solutions were then added together, and formed a liquor which was transparent, and of a greenish-yellow colour.

1. Prussiate of pot-ash produced a copious precipitate of molybdæna, in the form of a reddish-brown flocculent matter.

B. Lixivium of carbonate of pot-ash precipitated a yellowish-white matter, and turned the liquor to a deep blue.

C. Carbonate of soda had the same effect.

D. Solution of carbonate of ammoniac produced a similar precipitate, and caused the liquor to become blue.

acid before any precipitation could be made. The cause of this was, that the first liquor contained nitric acid in excess, which was afterwards expelled by the subsequent evaporations.

These precipitates were separately collected and washed on filters.

When examined by the blow-pipe, all of them afforded a yellowish-green glass, with phosphate of ammoniac and soda.

These precipitates dissolved in diluted nitric acid with effervescence, and sulphuric acid precipitated sulphate of lead, after which Prussian blue was precipitated by prussiate of pot-ash, and the liquor became brown.

E. The blue solution, which consisted of the muriatic and molybdic acids combined with soda, was evaporated.

When the liquor became hot, the colour changed from blue to pale yellow, and the evaporation was continued without any other perceptible alteration till the whole was become a dry concrete salt.

I dissolved this salt in distilled water, and added muriatic acid, so as to be in a small excess. The liquor was then evaporated to half, and was set in a cool place.

The following morning I found a quantity of crystallized muriate of soda at the bottom of the bason, covered with a white flocculent precipitate, which I collected and edulcorated on a filter. The rest of the liquor was repeatedly evaporated, till I had separated the greatest part of this white matter from the muriate of soda.

The last portion of the liquor, however, still contained some molybdic acid, combined with the muriate of soda; for after it had been several times evaporated and again dissolved, it became blue when muriate of tin was added; or if muriatic acid was first poured in, prussiate of pot-ash produced a reddish-brown precipitate of molybdæna.

Experiments on the White Precipitate.

1. It was not dissolved when water was boiled on it.

2. When digested with sulphuric or muriatic acid, the greatest part was dissolved, and prussiate of pot-ash produced a precipitate of a greenish-brown colour.

3. A small part became yellow when nitric acid was distilled from it.

4. The solutions of carbonate of pot-ash, soda, and ammoniac, dissolved the greater part; and when these solutions were saturated with muriatic acid, prussiate of pot-ash produced precipitates like those of the acid solutions.

As this precipitate in a great measure resembles that which is described in § X. I shall, when I come to that part, give a more ample account of it.

F. I next examined the blue solution, which consisted of the muriatic and molybdic acids combined with ammoniac.

It was first filtrated, and then gradually evaporated. When evaporated to half of the original quantity, the colour was green, but towards the end of the operation it again became blue, and when evaporated to dryness, the residuum was a whitish salt, tinged in some parts with blue.

G. This salt was reduced to powder, and was put into a small glass retort, to which a receiver was fitted. I then placed the retort in a small open furnace, and gradually raised the fire till the bottom of it began to melt. The retort was now removed, and I examined the contents. The receiver contained some water, and a small quantity of muriatic acid.

Near the extremity of the beak of the retort was some muriate of ammoniac, with some fuming muriatic acid, and the

remainder of the tube was filled with a hard greyish-blue salt. In the retort was a black pulverulent residuum.

I collected all of the blue salt, and again sublimed it, and again obtained muriatic acid, blue salt, and some of the black powder.

The blue salt was composed of muriate of ammoniac combined with the acid, or rather with a blue oxyde of molybdæna.

H. The black residuum was put into a glass retort, and some nitric acid being poured on it, it was exposed to a moderate heat. Nitrous fumes were discharged, and when the distillation had been repeated, I found the whole of this black powder converted into the citron-coloured molybdic acid.

I had evident proof that in this experiment a portion of the muriate of ammoniac was decomposed by each sublimation, and also that part of the molybdic acid was deprived of oxygen, and remained in the retort, if not in the state of metal, at least combined with so small a quantity of oxygen as to be nearly approaching to it.*

Molybdate of Lead with Muriatic Acid.

EXPERIMENT II.

One drachm of the ore was digested with muriatic acid, and distilled water was added till the whole was dissolved, excepting a small residuum of siliceous earth.

The solution was filtrated, and was repeatedly evaporated, till muriate of lead was no longer separated.

* A black powder of a similar nature appears to have been obtained by SCHEELE, when he distilled the white molybdic acid with a small quantity of olive oil. Essays, p. 238.

The muriate of lead, when edulcorated, I found to be perfectly free from any other substance.

I now saturated the acid solution (from which the muriate of lead had been separated) with solution of carbonate of ammoniac, and obtained a pale yellow flocculent precipitate, which was well edulcorated.

This precipitate immediately dissolved in very dilute nitric acid, and with sulphuric acid I precipitated a small portion of lead, after which, with prussiate of pot-ash, I separated a quantity of iron.

The solution, when saturated with the ammoniac, was deep blue, and was composed of muriatic acid, ammoniac, and the blue oxyde of molybdæna, like that mentioned in the former experiment.

In the course of these experiments, I have observed that the full blue colour only takes place at the precise moment of saturation, and if the alkali is even added to a considerable excess, the colour does not suffer any farther change; but if much water is first added, the blue colour does not appear; or if water is added afterwards, the solution becomes colourless.

By the preceding experiments the component parts of the ore are proved to be lead, iron, and molybdic acid.

In respect to the small portion of siliceous earth, it may rather be regarded as accidentally present, than as an essential ingredient.

My second object was to discover the least exceptionable mode of analysis, but all of those which have been described appeared to me to be liable to considerable objections, and I was therefore induced to make some additional experiments.

§ X. *Molybdate of Lead with Sulphuric Acid.*

From the experiments of Mr. KLAPROTH it appears, that he only employed nitric and muriatic acid; and on this account I was desirous to try the effects of sulphuric acid, especially as SCHEELE has proved that it is able to dissolve a considerable quantity of the acid of molybdæna.* Moreover, I conceived hopes of success, on the supposition that the elective attraction between lead and sulphuric acid was more powerful than that between lead and molybdic acid; and as sulphate of lead is nearly insoluble, I should thus be able to make a complete separation of the constituent parts of the ore, I therefore made the following experiment.

120 Grains of the purified ore in fine powder were put into a small glass matrass, and one ounce of concentrated sulphuric acid was poured on the powder.

The matrass was then placed over an ARGAND lamp, and the acid was boiled during an hour. The ore became white, and the acid was of a beautiful blue.

When it had stood some hours, I poured the acid into another vessel, edulcorated the powder with distilled water, and added the washings to the acid solution.

Another ounce of sulphuric acid was poured on the powder, and boiled as before. It was faintly tinged with blue; and I added it to the first solution, as well as the water with which the powder was washed.

That I might not leave any part of the molybdic acid unextracted, I repeated the operation a third time. The powder

* Essays, p. 235.

was then edulcorated, and the acid solutions being added together, formed a pale blue transparent liquid.

To decompose the white residuum, I boiled it during an hour with lixivium of carbonate of soda, then washed the powder, and poured on it nitric acid much diluted, by which it was immediately dissolved with effervescence, leaving a very small residuum of siliceous earth.

Prussiate of pot-ash produced a white precipitate of lead, and after 12 hours, a very small portion of Prussian blue subsided.

The ore was therefore decomposed, and there only remained this minute portion of iron to be separated from the lead; but this I shall notice when I come to the analysis.

I now diluted the sulphuric solution with a large quantity of distilled water, and divided it into two portions.

One of these (which I shall call A) was saturated with carbonate of pot-ash. The other (B) was saturated with carbonate of ammoniac.

When the alkalies were first added, the solutions became of a pale yellowish green, and as the quantity of the alkalies was increased, the solutions changed to bluish green, and lastly to deep blue.

When the vessels had stood about 24 hours, the solution A deposited a white precipitate, and in the solution B there was also a small quantity of a yellowish colour.

Both solutions passed the filter without any diminution of the blue colour.

I collected the white precipitate of A on a filter, and then evaporated the liquor to half.

The following morning I found a large quantity of crystal-

lized sulphate of pot-ash covered with a flocculent white precipitate. This I separated from the sulphate of pot-ash, and by repeated evaporations obtained the remainder.

These white precipitates were kept separate in the order in which they were obtained, and were washed and dried.

Experiments on the first Portions of the White Precipitate obtained by the Addition of the Alkali, and by the first Evaporation.

The white precipitate, when exposed on charcoal to the blow-pipe, melted into a pale green transparent globule.

With borax it formed a yellow transparent glass when hot, which as it cooled became opaque, and of an ash colour.

When added to the phosphate of ammoniac and soda in fusion, a yellowish green transparent glass was produced.

Water boiled for a considerable time on the precipitate did not apparently dissolve it; but muriate of barytes shewed the presence of a small quantity of sulphuric acid.

Nitric acid distilled to dryness from some of the precipitate, produced very little alteration, excepting that a small part became yellow.

Sulphuric acid was digested on a portion of the precipitate, and dissolved part of it; the remainder appeared unchanged.

The solution was diluted with distilled water, and prussiate of pot-ash being added, produced a blue precipitate.

Muriatic acid digested on another portion, turned it at first yellow, but afterwards the greater part became white, and remained undissolved.

The solution afforded a blue precipitate with prussiate of

pot-ash, and a small quantity of white precipitate with muriate of barytes.

The residuum was not affected when afterwards digested with acids or alkalies.

Some of the white precipitate was boiled with lixivium of carbonate of pot-ash, and part was dissolved. The solution was then saturated with muriatic acid, and prussiate of pot-ash produced a blue precipitate.

With carbonate of soda the effects were the same.

A solution made with carbonate of ammoniac (afterwards saturated with muriatic acid) was tinged green by the addition of prussiate of pot-ash.

A mixture, composed of 20 grains of the precipitate, and 50 grains of sulphur, was put into a small glass retort, and distilled till all of the sulphur was driven over.

The powder in the retort was of a pale grey colour, did not stain the fingers, or feel greasy, and had an hepatic smell.

Diluted nitric acid was digested on it without heat, and when prussiate of pot-ash was added to a part of the clear solution, a brown cloud was produced in about 10 minutes, resembling the usual precipitate of molybdæna.

Lixivium of carbonate of pot-ash added to another portion, formed a white flocculent precipitate, like starch.

Concentrated nitric acid was afterwards digested on the grey powder in a strong heat, and dissolved a considerable part.

With this solution, prussiate of pot-ash produced a brown precipitate, intermixed with some blue particles.

The rest of the solution was then evaporated, and left a bright yellow mass at the bottom of the matrass.

The undissolved residuum of the nitric solution was then boiled with lixivium of pot-ash, which was afterwards saturated with muriatic acid, and became tinged with blue when prussiate of pot-ash was added.

The residuum was now a black powder, which was edulcorated, and was immediately dissolved when nitric acid was poured on it; at the same time nitrous fumes were emitted. The solution was transparent, excepting that a few white particles were floating in it.

It was then diluted, and filtrated.

Prussiate of pot-ash turned it to a brownish-green, which afterwards became brown. Lixivium of pot-ash precipitated a white flocculent matter; and caustic ammoniac, added to a third portion, precipitated a quantity of iron.

As this precipitate had some remarkable properties, particularly in respect to the difficulty with which it was decomposed, I have been induced to mention the experiments made on it in a circumstantial manner.

This precipitate appears from these experiments to be principally composed of iron, and some molybdic acid, together with a small portion of alkali and sulphuric acid.

The intimate union between the iron and molybdic acid is apparently the cause which impedes the decomposition of this precipitate; but this can only be ascertained by future experiments on molybdate of iron.

I next examined the white precipitate which was deposited by the last evaporations, and found that (when distilled with nitric acid) it was converted into the yellow molybdic acid; and I was therefore convinced that this last portion of the

white precipitate was the same neutral salt which I obtained in several other operations, and which has also been noticed by SCHEELE and KLAPROTH.*

I now began to examine the blue solution B, which consisted of the sulphuric solution of molybdic acid, saturated with ammoniac; but that the experiments made on this may be better understood, I shall first give an account of some experiments and observations which I have made on the sulphate of ammoniac.

Experiments and Observations on the Sulphate of Ammoniac.

This neutral salt, which from GLAUBER (who first prepared it) was called the secret ammoniacal salt of GLAUBER, or vitriolic ammoniac, has been very little examined; neither has it been applied to any useful purpose, although the inventor much recommended it in metallurgical operations.

It has been long known that the fixed alkalies, lime, and barytes (when triturated with it), decompose it, by uniting with the acid. But the effects of heat on it do not appear to have been sufficiently observed.

MACQUER says, that it is (to use his expression) demi-volatile, that it may be sublimed entire, and that it cannot be decomposed in close vessels without some intermediate substance.†

BAUME' makes use of nearly the same expressions.‡

* SCHEELE observes, when molybdæna was detonated with nitre, and the mass afterwards dissolved in water, and saturated with sulphuric, nitric, or muriatic acid, that a white precipitate was produced, which was the acid of molybdæna combined with a portion of alkali. Essays, p. 231, and 240.

† *Dictionnaire de Chimie*, Tom. I. p. 111.

‡ *Chimie Expérimentale et Raisonnée*, Tom. II. p. 83.

BUCQUET says, that when it has lost the water of crystallization, it becomes red hot, and melts without being volatilized.

Lastly, M. FOURCROY mentions it in the following manner: "As it contains much water of crystallization, it immediately liquefies by a very moderate heat; but by degrees it "becomes dry, in proportion as the water of crystallization is "dissipated. In this state it first becomes red hot, and soon "melts without being volatilized, according to BUCQUET; but "M. BAUME' asserts that it is demi-volatile. In repeating "this experiment I have observed, that in fact a part of this "salt is sublimed, but a *portion remains fixed in the vessel*, and "without doubt it is concerning this that BUCQUET speaks."*

When so many eminent chemists concurred in nearly the same assertion, I was not a little surprised to observe, in some experiments (which I made for a very different purpose), that the whole of the sulphate of ammoniac was not only volatilized by heat, but also that the distillation of it was accompanied with some remarkable phænomena.

I therefore diluted some very pure concentrated sulphuric acid with an equal quantity of distilled water, and having saturated it with ammoniac, I gradually evaporated it till it became a concrete salt.

EXPERIMENT I.

I put two ounces of the salt into a glass retort, capable of containing three times the quantity, then fitted on a receiver without any luting, and placed the retort in a small open furnace over some lighted charcoal.

The salt in the retort speedily liquefied, and a small portion

* *Elémens d'Histoire Naturelle et de Chimie*, Tom. II. p. 93.

of water first came over; this was succeeded by a considerable quantity of alkaline gas, which continued to be produced during 15 or 20 minutes. On a sudden the vessels were filled with a thick white cloud, which upon close inspection appeared to be composed of very minute glittering crystals. This cloud quickly disappeared, and was followed by a great quantity of sulphureous gas and water, the greatest part of which was condensed in the receiver; and the operation went on in this manner while any thing remained in the retort.

During the distillation, the matter in the retort was always liquid; and when the operation was finished, I found in the receiver a considerable quantity of sulphureous acid, with some ammoniac in solution; and in the neck of the retort there was sublimed a portion of the undecomposed salt.

From this experiment I was in a great measure convinced, not only that the neutral salt was decomposed, but that the ammoniac was also in part resolved into its constituent principles.

EXPERIMENT II.

That I might, however, remove any doubt respecting this matter, I fitted a bent glass adopter to a retort, and to this added a double tubulated receiver, from which proceeded a bent tube, which passed under a glass jar filled with water and inverted.

The former experiment was now repeated with this apparatus; and I had the satisfaction to observe, that when the sulphureous acid began to be produced, a quantity of gas at the same time displaced the water in the jar, and continued to pass into it to the end of the operation.

This gas I afterwards examined, and found that it possessed all the properties of the azotic gas.*

I afterwards distilled 100 grains of the yellow oxyde of iron, mixed with 200 grains of sulphate of ammoniac.

Pure ammoniac first came over, and afterwards some sulphureous acid. When the retort began to melt I removed it, and found the iron chiefly in the state of the red oxyde, or colcothar, mixed with some sulphate of iron.

When oxyde of zinc was used, the residuum was sulphate of zinc.

Minium, when triturated with sulphate of ammoniac, immediately decomposed it like lime, or the alkalies, and when distilled, the retort contained sulphate of lead.

When native green oxyde of copper was distilled with sulphate of ammoniac, the residuum was partly red oxyde of copper, with some sulphate of the same. But the ammoniac came over in a concrete state, by reason of the carbonic acid contained in the green oxyde.

The oxydes therefore of iron, zinc, lead, and copper decompose the sulphate of ammoniac by combining with the acid.

I next mixed it with the yellow tungstic acid; but after the distillation, I found the tungstic acid unchanged, excepting that it had acquired a tinge of pale green. The ammoniac

* This operation requires to be conducted with caution; for at the moment when the white cloud appears, a vacuum takes place, occasioned by the alkaline gas (which previously filled the vessels) being neutralized by the sulphureous gas, which is then produced. It is necessary, therefore, in about 10 or 15 minutes after the commencement of the operation, that the fire should be raised, and the azotic gas will then soon begin to pass into the jar. Some water will most commonly rush into the receiver, but if the capacity of this is not too small, there will not be time enough for the water to rise sufficiently high, so as to pass into the retort.

and the sulphureous acid also came over in the same manner as when only the sulphate of ammoniac was distilled.

Lastly, I distilled one ounce of the sulphate of ammoniac with 20 grains of the yellow molybdic acid. During the distillation, the ammoniac and sulphureous acid were produced in as great quantities as when the sulphate of ammoniac was distilled by itself. But the molybdic acid remained in the retort, deprived of oxygen, in the form of a black blistered matter, which was again converted into the yellow acid when distilled with nitric acid.

From these experiments it appears, that the sulphate of ammoniac is not (as many eminent chemists have imagined) incapable of being decomposed without some intermediate substance, but on the contrary, the whole of it can be raised, and a great part decomposed, whenever a proper degree of heat is applied; for then a certain portion of ammoniac first comes over, so that the remainder is combined with acid in excess, and the hydrogen of the ammoniac which remains unites with part of the oxygen of the sulphuric acid, and forms water, which passes into the receiver, accompanied by the acid (now become sulphureous acid), and by the azote in the state of gas.

Various methods have long been in use to decompose ammoniac.

Metallic oxydes produce this effect; and SCHEELE particularly mentions, that if arseniate of ammoniac is distilled, gas is produced, and the acid of arsenic is reduced to the metallic form, and as such is sublimed.*

* Essays, page 155. The same effects also were produced when acid of arsenic was sublimed with muriate of ammoniac, page 161.

The decomposition of the nitrate of ammoniac is also well known; and I have no doubt but that muriate of ammoniac suffers a similar decomposition in a smaller degree each time that it is sublimed; for whenever I have had occasion to sublime muriate of ammoniac, I have always found some fuming muriatic acid; and from whence could this be produced, but from a portion of the salt which was decomposed during the sublimation.

The distillation of the blue triple salt, composed of molybdic acid, muriatic acid, and ammoniac (§ VII. and IX.), places this in a stronger light; for whenever this salt was distilled, a certain portion of molybdæna was left in the retort deprived of oxygen, and muriatic acid was found in the receiver. Moreover, from several repetitions of this experiment, I am well convinced, that by a great number of sublimations the whole of the molybdæna might have been obtained in the proportion that the muriate of ammoniac was decomposed.

When all these facts are considered, it appears to me more than probable that most, if not all, of the ammoniacal salts suffer different degrees of decomposition whenever they are treated in the dry way.

As the molybdic acid was my principal object, I did not make all the experiments I could have wished on this neutral salt; neither have I as yet exactly determined the proportion of azotic gas produced from a certain quantity.

I have found, however, that the sublimed undecomposed part of the salt amounted to 183 grains when an ounce of the salt had been distilled, and that the liquid in the receiver weighed 145 grains; so that 152 grains had escaped, which

principally consisted of azotic gas, together with some sulphureous acid, and some alkaline gas, which had made their way out of the vessels during the operation.

Continuation of the Experiments on the Molybdate of Lead.

From the effects which I observed to be produced when sulphate of ammoniac was distilled with molybdic acid, I was induced to examine in a similar manner the blue solution B; but first I collected, washed, and dried the pale yellow precipitate which had been formed when the sulphuric solution of the molybdic acid was saturated with ammoniac.*

This precipitate, when dry, appeared of a deeper yellow, and easily dissolved in muriatic acid.

Prussiate of pot-ash was then added to the clear solution, and precipitated the whole of the dissolved matter in the state of Prussian blue.

The filtrated solution B was now evaporated till it became a dry concrete salt, the colour of which was pale greyish blue.

I collected this salt, and having reduced it to powder, put it into a small glass retort, and having fitted on a receiver, I distilled it in the same manner as was employed with the sulphate of ammoniac.

The products which came over were also the same, and when the bottom of the retort began to be softened by the

* Whenever the solution was sufficiently diluted, I always found that ammoniac precipitated the iron free from any part of the molybdic acid; but if either of the fixed alkalies were used, a portion of molybdic acid was precipitated with the iron in a state similar to the first portions of those white flocculent precipitates, which have been already mentioned in § IX. and § X.

heat, I removed it, and found the residuum to be a black blistered matter.

I then examined the sulphureous acid and sulphate of ammoniac which had risen, but did not find any trace of molybdæna.

I next poured nitric acid diluted with an equal weight of distilled water on the black residuum in the retort, and distilled it.

As soon as the acid began to be warm, nitrous fumes were discharged, and when the distillation had been repeated with a second portion of nitric acid, I found the whole of the black matter converted into a pale citron-coloured substance, which was the molybdic acid.

I shall not here mention the experiments made on this acid, but shall speak of them after I have given an account of the analysis of the molybdate of lead, which I immediately attempted, according to the method pointed out by the foregoing experiments.

§ XI. *Analysis of the Molybdate of Lead.*

I put 250 grains of the purified ore reduced to a fine powder into a glass matrass, and having poured on it one ounce of concentrated sulphuric acid, I digested it in a strong heat during an hour.

When the solution was become cool and had settled, the acid was cautiously decanted from the powder, and distilled water was poured on till it came away tasteless.

The same operation was repeated twice, so that three ounces of sulphuric acid were used.

The acid solutions and washings were then filtrated, and were received in a large glass vessel.

I diluted the pale blue liquor with distilled water, in the proportion of sixteen to one, and afterwards gradually added ammoniac, until it was completely saturated. The liquor then became deep blue, and appeared turbid.

When it had stood about 24 hours, a loose pale ochry precipitate subsided, and was collected on a filter, the weight of which had been noted.*

This precipitate was edulcorated, and afterwards dried with the filter on the flat top of a tin vessel heated by boiling water, after which the weight of the precipitate was 4.2 grains.

The colour of the dry precipitate was yellowish brown, and when dissolved in muriatic acid it was precipitated by prussiate of pot-ash in the state of Prussian blue.

I now poured part of the clear blue solution, which was composed of sulphuric and molybdic acid saturated with ammoniac, into a glass retort, and when about half was evaporated, I continued to add the remainder of the liquor at different times till the whole was become a concrete salt.

I then raised the fire and continued the distillation until all of the sulphate of ammoniac was decomposed or driven over; but as some of the sublimed salt was fixed in the neck of the

* This is one of the many instances which prove the weak affinity between molybdæna and oxygen; for it is well known that pure ammoniac precipitates iron from sulphuric acid, in a state nearly similar to martial ethiops; but in the present case the iron takes a considerable portion of oxygen from the molybdic acid at the moment that the acid menstruum is saturated by the ammoniac, and it is therefore precipitated in the form of a yellowish-brown oxyde, whilst the molybdic acid being thus deprived of so large a quantity of oxygen, is converted into a blue oxyde which remains in solution.

retort, I turned the bottom of it upwards, and poured some distilled water into the neck, so as to wash out the salt; after this I increased the fire until the whole body of the retort was become red hot.*

The residuum in the retort was a black blistered mass, upon which I poured three ounces of nitric acid diluted with an equal portion of water, and having distilled it, I repeated the operation, and thus converted the whole of the black matter into the yellow acid of molybdæna.

When the retort was sufficiently cooled, I cut off the neck and removed the powder, which weighed 95 grains.

I next proceeded to decompose the residuum left by the acid solution in the state of sulphate of lead, and having edulcorated it, I boiled it during an hour with four ounces of lixivium of carbonate of soda, then washed the powder, and poured on it nitric acid much diluted.

The whole was dissolved, excepting a small portion of white powder, which was washed and dried on a filter by the heat of boiling water, and then weighed seven-tenths of a grain.

This, upon examination, proved to be siliceous earth.

I then exactly saturated the nitric solution with lixivium of pure or caustic soda, and having washed and dried the precipitate of lead, I exposed it in a porcelain crucible for a quarter of an hour to an heat rather below red; after which it weighed 146 grains.

As I had found by a former experiment that a small portion of iron remained with the lead, I dissolved the 146 grains in diluted nitric acid, and precipitated the lead by sulphuric acid.

* To be certain that all of the ammoniacal salt is decomposed, it is absolutely necessary that the retort should be made red hot.

The solution was then filtrated, and being saturated with pure ammoniac, I obtained a small quantity of oxyde of iron, which, when dried as before, weighed one grain.

By this analysis, 250 grains of the ore yielded

		Grains.
oxyde of lead — —		146
molybdic acid — —		95
oxyde of iron { Grs. 4 2 / 1 } —	5	2
and siliceous earth —	0	7
grs.	246	9
the loss was therefore —	3	1
	250	0

which I am inclined to place principally to the account of the lead, as it is scarcely possible to decompose the sulphate of lead without some loss, occasioned by the action of the alkaline solution.

§ XII. *Experiments on the yellow Molybdic Acid, obtained by the Analysis.*

A. When exposed to the blow-pipe on charcoal, it was melted by the exterior flame, and the sides of the charcoal were covered with small long crystals, which had a metallic lustre resembling silver.*

When the heat was continued the whole was melted, and

* Scheele mentions a similar product obtained when molybdæna was exposed to the blow-pipe. Essays, p. 230.—Also by sublimation. Essays, p. 238.—And *Mémoire sur la Molybdène, par M.* Pelletier. *Journ. de Physique, Decembre*, 1785, p. 439.

for the greater part absorbed by the charcoal, the edges of which became covered with a blue powder.

When melted in a spoon of platina, some yellow powder was deposited near the edges, and a brownish-yellow shining matter was formed, which became streaked in cooling.

With borax it produced a brownish-yellow glass, but if the quantity of molybdic acid was small, the colour was sometimes blue when the globule was heated by the interior flame.

With soda in the platina spoon it formed a brownish opaque matter.

And with phosphate of ammoniac and soda it formed a glass, which (in proportion to the quantity of molybdic acid) varied from a greenish blue to a deep blue.

B. Ten grains of the yellow molybdic acid were boiled with six ounces of distilled water. About three grains were dissolved, and the solution when filtrated was of a pale yellow colour.

It had scarcely any perceptible flavour, but turned litmus paper red.

When prussiate of pot-ash was added to a portion of the solution, no apparent change was effected; I therefore added a small quantity of nitric acid, which produced a copious brown precipitate of molybdæna. The sulphuric and muriatic acids had the same effect, when poured into the solution, either before or after the addition of prussiate of pot-ash.

With muriate of tin it changed to a beautiful deep blue.

Lead was precipitated from solution of nitrate of lead, in the form of a pale yellow precipitate, which was a regenerated molybdate of lead.

Nitrate of barytes rendered the solution slightly turbid, but

I did not find that the precipitate which subsided was soluble in cold water, as SCHEELE has mentioned.*

The solution did not precipitate lime from nitric acid.

C. Ten grains of the yellow molybdic acid were dissolved when digested with an ounce of concentrated sulphuric acid.

The solution as it cooled became blue.†

Prussiate of pot-ash produced a reddish-brown precipitate.

Muriate of tin had not any effect.

When a portion of the solution was distilled to dryness, the yellow molybdic acid was left in its original state.‡

The remainder of the solution was saturated with lixivium of soda, by which the blue colour was heightened, and some white flocculent matter was precipitated.

Prussiate of pot-ash added to part of this saturated solution did not precipitate the molybdæna, until the alkali was again supersaturated with an acid.

Muriate of tin poured into the solution saturated with alkali changed it to a deep blue; but when the alkali was again saturated with an acid the muriate of tin ceased to have any effect.

The white flocculent matter which was precipitated when

* Essays, p. 234.—SCHEELE does not mention the quantity of water which he employed.

† SCHEELE observes that sulphuric acid dissolves a considerable quantity of molybdic acid, and that the solution as it cools becomes blue and thick; but when heated, the colour disappears, and returns again as the liquor grows cold. Essays, p. 235.

‡ M. PELLETIER says, that a small portion of molybdæna is raised by sulphuric acid when distilled with it; but I did not find it so with the molybdic acid.—*Mém. sur la Molybdène, Journ. de Physique, Decembre*, 1785.

the solution was saturated with soda, was edulcorated and heated with nitric acid, by which it was converted into a yellow powder, similar to the molybdic acid which had been dissolved.

D. Ten grains of the yellow molybdic acid, when digested in a strong heat with one ounce of concentrated muriatic acid, formed a pale yellowish-green solution.

Prussiate of pot-ash precipitated the molybdæna.

Muriate of tin had not any effect.

A portion of the solution being distilled to dryness, left a greyish-blue residuum.*

I then saturated the remaining part of the solution with lixivium of pot-ash, by which the blue colour became more apparent, and a much larger quantity of white flocculent matter was precipitated than when soda was employed.

Prussiate of pot-ash did not affect this solution, until the alkali was again saturated with an acid.

Muriate of tin was precipitated by the solution saturated with alkali, highly coloured with blue; but when the alkali was again saturated with an acid, the muriate of tin had not any effect.†

* SCHEELE has made the same observation. Essays, p. 235.

† From the effects produced by muriate of tin on the molybdic acid dissolved in water, in acids, and in alkalies, it appears that it always tends to deprive the molybdic acid of a great part of its oxygen; and when water is the menstruum, the muriate of tin does this effectually; but when the molybdic acid is dissolved in sulphuric or muriatic acid, the muriate of tin has not any effect, because (as I conceive) the oxygen is supplied by the acid menstruum. This seems the more evident from the effects produced by the muriate of tin when the excess of acid is saturated by an alkali.

Lastly, the white flocculent matter was boiled with nitric acid, and became like the molybdic acid before it was dissolved.

E. Nitric acid did not appear to have any effect on the molybdic acid when digested with it.

F. Two ounces of lixivium of carbonate of pot-ash were poured on ten grains of the molybdic acid.

In a few minutes, carbonic acid was gradually expelled, and as the molybdic acid dissolved, a white flocculent matter was deposited.

After it had stood some hours, the clear liquor was decanted from the residuum.

Prussiate of pot-ash did not affect this solution. Some nitric acid was then dropped in, and produced a reddish-brown precipitate, which was redissolved until the acid was in some excess.

Muriate of tin, when added to a portion of the alkaline solution, was precipitated white, but when some muriatic acid was dropped in the precipitate became blue.

The white flocculent residuum, when treated with nitric acid as in the former experiments, was converted into the yellow molybdic acid.

Another portion of the alkaline solution was evaporated to one-fourth, and in proportion as the evaporation advanced, some of the white flocculent matter was precipitated, but I did not obtain any crystals.

G. Two ounces of lixivium of carbonate of soda were poured on ten grains of molybdic acid.

In a few minutes carbonic acid was expelled, and when the

molybdic acid was dissolved, a small quantity of white flocculent matter was precipitated.

The clear solution was then poured from the residuum.

Prussiate of pot-ash did not produce any precipitate until the alkali was saturated with an acid.

The effects of muriate of tin were also the same as those mentioned in the former experiment.

A part of the solution was evaporated to half, and the next morning I found crystals, which although not very distinct, appeared to be in the form of four-sided tables with the angles truncated.

These crystals dissolved in water without leaving any residuum, and (when the solution was saturated with muriatic acid) the molybdic acid was precipitated by prussiate of pot-ash, as in the former experiments.

H. Two ounces of carbonate of ammoniac in solution were poured on ten grains of molybdic acid, which appeared to be more readily dissolved than when the fixed alkalies were employed.

The solution appeared slightly turbid, but very little of it was precipitated.

The effects produced by prussiate of pot-ash and muriate of tin were the same as in the preceding experiments.

When a portion of the solution was distilled to dryness, part of the molybdic acid remained unchanged, but another part was deprived of oxygen, and appeared in the form of a dark grey powder.*

The remaining part of the solution was considerably eva-

* SCHEELE has observed a similar effect.

porated; and the following day I found a striated yellowish mass, which dissolved in water without leaving any residuum. This solution resembled the former in every respect.

§ XIII. *Molybdic Acid with Sulphur.*

In order to remove every doubt concerning the nature of the yellow acid obtained by the analysis, I made the following experiment.

I put 20 grains of the yellow acid and 100 grains of sulphur into a small glass retort, and continued the distillation till the bottom began to melt.

The residuum was a black substance, which was greasy to the touch, stained the fingers black, communicated to them a shining metallic lustre, and had all the other properties of the mineral known by the name of Molybdæna.

I afterwards distilled this black matter with nitric acid, which converted it into a yellow powder, similar in appearance and properties to the molybdic acid which had been originally employed.

§ XIV. *General Observations.*

It has been proved in the course of this paper that molybdate of lead can be decomposed in the humid way by the fixed alkalies, although these have not any effect when boiled with molybdæna mineralized by sulphur.* The state of the molybdæna in the two substances appears to be the cause of this

* Scheele's Essays, p. 230; and *Mémoire sur la Molybdène, par* M. Pelletier. *Journal de Physique*, 1785, p. 437.

difference, for in the former it is oxygenated, but in the latter I conceive it to be in the state of metal.

From the experiments of SCHEELE it also appears, that of all the known acids only two have any effect on the sulphurated molybdæna, and that these two are the nitric acid, and that of arsenic. The latter, however, seems rather to act on the sulphur than on the molybdæna; but the former communicates oxygen to both, so as to convert the one into sulphuric and the other into molybdic acid.

The rapidity with which nitric acid oxygenates molybdæna, even to supersaturation, resembles the effects produced by the same acid on some other metallic substances, particularly tin; for in both cases the acid ceases to act as soon as the supersaturation with oxygen is effected; and on this account the nitric acid is unable to dissolve the molybdic acid.

Before I proceed, I must observe that whenever a solution of the molybdic acid becomes blue, or tending towards that colour, it is a certain sign that the molybdic acid has suffered a diminution of oxygen. A variety of facts which prove this, have been already brought forward in the different experiments contained in this paper; and I shall soon have occasion to mention others.

Sulphuric acid can dissolve a considerable quantity of molybdic acid; and the solution is always more or less of a blue colour according to the quantity which is dissolved; and the blue colour proves that the molybdic acid has parted with a portion of oxygen; but if the solution be heated, the blue colour disappears, and returns again when the liquor becomes cold.*

* If lead or any other metal is present, the blue colour is permanent.

The cause of this I believe to be a change produced by heat in the respective degrees of affinity which prevail between the metallic base and oxygen, and between the base of the acid menstruum and oxygen; so that when the solution is heated, the affinity between the blue oxyde of molybdæna and oxygen is increased, and a portion of oxygen therefore quits the acid menstruum and combines with the blue oxyde, which then becomes molybdic acid; but as soon as the heat is dissipated, the cause of this augmentation of affinity ceases, and the acid menstruum receives again the portion of oxygen from the molybdic acid, which then returns to the state of a blue oxyde; or if the heat is continued until the solution is distilled to dryness, the residuum is the molybdic acid exactly in the same state as it was before the solution was made, for the continuation of the heat enables it to retain the portion of oxygen requisite to constitute a metallic acid.

I do not therefore believe that the total quantity of oxygen in the solution suffers alteration any further than that it is distributed in different proportions between the two acidifiable bases, sulphur and molybdæna, according to the temperature of the solution.

As the affinity between azote and oxygen is comparatively weak, the metal molybdæna effects a decomposition of the nitric acid, and acquires a sufficiency of oxygen to become molybdic acid. But as the affinity between sulphur and oxygen is greater than that of azote, and also under certain circumstances superior to molybdæna, the latter requires the assistance of heat to be able to retain a full portion of oxygen, and this increase of affinity lasts no longer than during the continuation of the heat.

To corroborate this assertion, it will be proper to consider the effects of muriatic acid on that of molybdæna, especially as the affinity between the radical principle, or base of the muriatic acid, and oxygen is known to be so great, that no chemist has as yet been able to effect a separation of the constituent principles.

It has been mentioned, that molybdic acid when dissolved in muriatic acid also parts with some oxygen, and tinges the menstruum with a green colour. But heat does not enable it to take back the oxygen, for it augments the effects of the muriatic acid, which, when distilled, passes oxygenated into the receiver, and the molybdic acid is converted into a bluish-grey oxyde.*

These effects clearly prove, that heat in this case acts inversely to what it did when the nitric and sulphuric acids were the menstrua. For then the increase of affinity was between molybdæna and oxygen, but here it is in favour of the base of muriatic acid; so that by the continuation of heat, the muriatic acid carries with it into the receiver a certain portion of oxygen which it has taken from the molybdic acid, and the latter is left in the state of an oxyde.

From this it appears that muriatic acid uniformly tends to deprive the molybdic acid of a certain quantity of oxygen, and that heat produces a contrary effect on this solution to that which it did on the one made with sulphuric acid; and heat and cold do not therefore produce a change of colour.

I do not, however, believe that muriatic acid acts thus constantly on all of those metals which can be dissolved by it; on the contrary, there is a muriatic solution which much re-

* *Elémens d'Hist. Nat. et de Chimie, par M. de* FOURCROY, Tome II. p. 439.

sembles the sulphuric solution of molybdic acid in the vicissitudes of colour which it exhibits by heat and cold.

The phænomena which heat produces on the solution of cobalt in muriatic or nitro-muriatic acid, called sympathetic ink, have long engaged the attention of chemists and others, but as yet great difficulties have occurred whenever an explanation has been attempted.

There can be no foundation for the idea which some have had, that the green colour (which characters traced with this solution on paper assume when heated) is caused by a temporary crystallization of the salt, and the disappearance of the colour by a subsequent degree of deliquescence; because any quantity of the liquid becomes green when heated.

The effects caused by heat on the sulphuric solution of molybdic acid have therefore induced me to suspect a similar cause in the muriatic solution of cobalt; and I believe that heat and cold in like manner causes a temporary difference to take place in the proportions of oxygen existing in the acid menstruum and the oxyde; and this is the more confirmed when the acid is expelled by too great a degree of heat, for then the changes of colour are no longer to be observed.

Heat, it is well known, assists the combination of oxygen with the metals, but I do not believe that the abovementioned alternate effects of heat and cold have been as yet investigated.

It is probable that these are not confined to the two instances which have been adduced, although in other solutions they may not be so apparent. The subject is certainly curious, and worthy of the attention of chemists, as it would reflect much light on the solutions of metals in general.

When the sulphuric or muriatic solutions of the molybdic

acid are saturated with pot-ash or soda, they assume a very deep blue colour at the moment of saturation. The molybdæna is not, however, precipitated in the form of the blue oxyde, but for the greater part remains combined with the acid menstruum and the alkali, and thus forms a triple salt in solution, which differs considerably from another triple salt, which is slowly precipitated at the time of saturation in the form of a white flocculent matter, and is composed of the same three ingredients, but contains the oxyde in the largest proportion.

Sometimes a fourth ingredient becomes added to the last mentioned white precipitate; for when iron is present in the sulphuric or muriatic solutions, it is precipitated by pot-ash or soda intimately combined with the other ingredients, and appears to render the decomposition of the precipitate very difficult.

Although the triple salt which is in solution will pass many folds of paper without leaving any residuum, yet it is not permanent; for by repeated evaporations, the neutral salt resulting from the combination of the acid menstruum and the alkali becomes crystallized, and a white flocculent matter is separated, which does not contain iron like that which was precipitated when the acid solution was saturated with the alkali, but can be converted into the yellow molybdic acid by being distilled with nitric acid, which takes from it the small portion of the acid menstruum and the alkali required to constitute the triple salt.

It has already been observed, that nitric acid has not any effect when immediately digested on molybdic acid, but I have found it otherwise when a third substance was present;

and the effects were nearly the same whether this substance was a metal or an alkali.

The portion of molybdic acid which I detected in the nitric acid employed to purify the ore, and Mr. KLAPROTH's experiments made with the same acid, prove the first, and the experiment mentioned in § VIII. is a proof of the latter.

The phænomena which appeared in the last experiment throw some light on the effects produced by nitric acid on molybdæna; for when the sulphuric and muriatic solutions of the molybdic acid were saturated with pot-ash or soda, they gradually changed to yellowish green, and so on to blue, in proportion as the alkali was added; but when nitric acid was added to the alkaline solution, the change of colour was exactly the reverse of the former, for the changes were then blue, green, and yellow, in proportion to the quantity of nitric acid.

The cause of these effects I conceive to be the different degrees of oxygenation of the molybdæna; for when the first portion of nitric acid was added, it rather combined with the alkali than with the molybdic acid, and the latter was therefore in some degree separated with a diminution of the original quantity of oxygen, and consequently appeared as the blue oxyde in solution. After this, the second portion of nitric acid began to oxygenate the blue oxyde, and therefore changed the colour of the solution to green; but the third addition of nitric acid acted immediately on the oxyde, turned the solution yellow, and when assisted by heat, caused a quantity of the yellow molybdic acid to be precipitated. The alkali, however, appears to have impeded the complete separation of the molybdic acid, and retained a part of it together with the nitric acid, so as to form a yellow triple salt.

When the sulphuric and muriatic solutions of the molybdic acid are saturated with ammoniac, triple salts are formed, which are different in their properties from those which have been described; for the triple salts produced by ammoniac are permanent, and do not appear to be decomposed by evaporation.

If iron is present in the acid solution (sufficiently diluted), it is precipitated by ammoniac free from molybdic acid, especially when the menstruum is the sulphuric acid.

The affinity of the molybdic acid with muriate of ammoniac is so great, that by sublimation it even in part quits lead to unite with it, and then forms the blue triple salt, from which the blue oxyde does not separate, but in proportion that it is deprived of oxygen by the gradual decomposition of the ammoniac caused by repeated sublimations.

When the sulphuric solution saturated with ammoniac is evaporated to a proper degree, the triple salt crystallizes in the usual figure of the sulphate of ammoniac, but the colour is bluish green. If, however, the evaporation is continued to dryness, a pale greyish-blue salt is left, and by distillation this salt is decomposed (after the manner of the decomposition which I have noticed in the sulphate of ammoniac), and the molybdæna remains in the form of a black powder, deprived of oxygen.

I think it necessary here to observe, that when molybdæna is not in the metallic state, it appears to me to suffer four degrees of oxygenation. The first is the black oxyde; the second is the blue oxyde; the third is the green oxyde, which (as it seems to be intermediate between an oxyde and an acid) I am inclined to call molybdous acid, according to the distinction made by the new Nomenclature; the last and fourth

degree is the yellow acid, or that which is supersaturated with oxygen.

The affinity between molybdæna and oxygen is but weak, at least in respect to that portion which is required to constitute molybdic acid; for it has been proved, in the course of these experiments, that considerable changes are produced by a very small difference in the proportions of the acids or alkalies, and even by the degrees of heat. SCHEELE and Mr. ISLMANN have observed, that all of the metals, excepting gold and platina, are able in the humid way to deprive the molybdic acid of oxygen, so as to cause it to become blue; but here their effects appear to cease. M. PELLETIER found that a solution of molybdic acid was turned blue when hydrogenous gas was passed through it. Mr. KLAPROTH has also remarked that light, under certain circumstances, changed the colour of molybdic acid to blue. And the effects of light appear in some measure to be connected with the following experiment.

I made a solution of the molybdic acid, by digesting sulphuric acid on molybdate of lead, and diluted it with an equal quantity of water. The solution was filtrated, and I then added a solution of hepar sulphuris until the brownish-red precipitate which was produced began to fall much paler. After this the liquor was filtrated, and was of a pale beer colour.

I placed it accidentally in an open glass jar, on a shelf near a window, on which the sun shone during a great part of the day, and was surprised to observe that in about two days it began to assume a greenish tinge, which gradually became deeper; on the third day it was of a full green, on the fourth it had a tinge of blue, on the fifth the colour was greenish-

blue, and on the sixth day it was changed to a beautiful deep blue.

The solution continued all the time to be transparent; and although the vessel remained four weeks in the same situation, the blue colour suffered no further change.

This solution much resembles that which SCHEELE discovered in the course of his experiments on manganese; but the apparent similar effects, I believe, are produced by opposite causes; for the changes of colour in the alkaline solution of manganese appear to be effected by the absorption of oxygen, but those of the molybdic solution are caused by a diminution of the inherent quantity.

The contrast of the causes which operate on the two solutions becomes the more evident when the effects which acids produce on them are considered; for when a few drops of an acid are added to the solution of manganese, the changes of colour are accelerated, not merely by the neutralization of the alkali and consequent precipitation of the manganese, but (as I conceive) by the accession of oxygen either immediately from the acid, or from the atmosphere, which the manganese is better able to absorb when the disengagement of it from the alkali is thus assisted by the addition of the acid.* On the contrary, if nitric acid is dropped into the molybdic solution, the colour is immediately destroyed, in the same manner as in all the other blue solutions of molybdæna when oxygen is thus presented to them.

The facility with which molybdæna parts with oxygen is evinced not merely in the humid way, for M. PELLETIER found that molybdic acid yielded oxygen to arsenic when

* SCHEELE's Essays, p. 108.

distilled with it, and that the latter was converted into a white oxyde.

The same is also proved by my experiments on various oxydes distilled with sulphate of ammoniac; for the molybdic acid was the only one which could thus be deprived of oxygen, not excepting the tungstic acid, which has been supposed much to resemble that of molybdæna.

XIII. *Observations of the diurnal Variation of the Magnetic Needle at Fort* Marlborough, *in the Island of* Sumatra. *By* John Macdonald, *Esq. In a Letter to* John Crisp, *Esq. F. R. S.*

Read April 21, 1796.

DEAR SIR, Fort Marlborough, 15th March, 1795.

I HAVE now the satisfaction to transmit to you the observations of the diurnal variation of the variation of the magnetic needle, with which you wished to be furnished. A short account of the mode used in laying off the meridian is prefixed. A small building, devoid of iron, was erected at some distance from my house. This building contained the meridian. By repeated observations, I found the sphere of mutual attraction of the needle and iron to be very small; a common-sized key presented to it, did not affect it at a nearer distance than 5 inches. To exclude every influence of iron, I laid aside such as might be about me, previous to the taking of the observations, and took care to remove the padlock and key, at the same time, to a certain distance from the constructure. The hasp and staple made use of for the padlock were of wood; and for the nocturnal observations, I had wooden candlesticks made. I may venture to say, that the observations were taken with the utmost care; and that every requisite precaution was used to exclude errors that might have arisen from a want of minute attention.

The observations contained in pages 346, 347, and 348, were taken by applying the magnet-box three times, each day, to the meridian. This was, I think, accurately effected, by hairs fixed longitudinally on the inside of the box, corresponding with projecting points on the outside. When these covered each other, and the meridian, to the eye looking through a magnifying glass from above, there was a strong presumption that the longitudinal axis and 0° points of the box were on and in the true plane of the meridian. In reading off, the right hand covered the right eye; a magnifying glass, of a power of $2\frac{1}{2}$, was held in the left hand; the upper axis-hair was brought to cover the 0° point; and the eye, hanging over this point, glanced steadily to the left, to read off the variation west from south, as the fine minute-scale was placed on the flat south end of the needle. This observation was taken each time four times, to ensure accuracy. Lest, however, any error might have arisen from not placing the box accurately in the same situation, in taking the three daily observations, two pieces of seasoned wood were fixed with wooden pins, nearly parallel to the meridian, on either side. The magnet-box was applied to the meridian between these, and kept firmly fixed in its position by a number of small wooden wedges, urged gently between the box and the lateral fixtures. The observations contained in page 349 were taken with the magnet thus fixed. A fourth column of observations, at various nocturnal hours, is given in page 349. A corresponding thermometrical observation is attached to each magnetic one. The thermometer was placed in the room on the left side of my hall.

It appears from these observations, that the east variation

diurnal of the variation, increased from about 7 in the morning till 5 in the afternoon, and that it decreased till 7 in the morning. The irregularities which are apparent do not destroy the general evident inference of result, as it is well known that the common increasing or decreasing variation is subject, in the same place, and on the same day, to certain deviations, from latent causes. It appears in general, that such diurnal variation of the variation as had been observed during thunder, is greater than it ought to have been, *cæteris paribus*.

It has been remarked, that heat weakens the magnetic virtue, and that cold strengthens it. Supposing, with the great HALLEY, the existence of 4 magnetic poles, by blending this supposition with the above principle, well ascertained, attempts have been made to account for the diurnal variation of the variation. The south-east magnetic pole being less heated in the morning, either by the sun or by subterraneous fire, than towards noon, and in the afternoon, and being at the same time, by passing through the meridian of Celebes, nearer Sumatra than the south-west magnetic pole, it draws to it in the morning the south end of the magnetic needle more powerfully than the other attracts; and, consequently, the variation diurnal of the variation ought to be, and actually is, less in the morning than in the afternoon. In the progress of the day, the south-east magnetic pole having become heated, and the south-west pole being at the same time less heated, attracts the south end of the magnetic needle more powerfully than the other does; and hence the east diurnal variation of the variation appears greater in the afternoon than in the morning. It is found in Europe, that this diurnal variation of the variation is greater in summer than in winter. This seems to point out

heat acting on magnets in the earth, as its efficient cause. This was first observed in Europe in 1756, by Mr. CANTON; and the results of the foregoing observation being diametrically opposite to his, with similar effects, afford not a small confirmation of the essential part of HALLEY's theory. The sciences of electricity and magnetism (in my opinion intimately connected) are at present in their infancy. We observe effects which we cannot trace up to any satisfactory cause. If observations similar to these, and to those made by Mr. CANTON, could be made in equal latitudes and longitudes, and in corresponding situations in the torrid zone, by collating the results, I think a rationale of this wonderful phænomenon might be obtained.

From the greatness of the angle of dip of the needle, I am led to suppose that the magnetic poles are fixed within the magnetic nucleus far within the earth's surface, and that some of these poles are more powerful in their action than others, from the variation observed in various places of the globe. I shall be happy if these observations (I mean the figured ones) will enable you to elucidate this subject.

I remain, with much esteem, &c.

JOHN MACDONALD.

24th of June. A meridian was drawn by means of the following apparatus. A plate of brass was cast, and reduced to a level surface in a lathe, in which concentric circles were accurately cut on it. A short hollow cylinder was screwed on the centre. This tube received a brass cylinder, pointed at the upper end. An iron-wood post was fixed in the ground. The brass plate was fixed level on the post by means of a gunner's

perpendicular, and strong screws working in two plates, on the principle of the levelling screws of a theodolite. The cylinder was rendered perfectly perpendicular to the level plate, by means of three small adjusting screws on the tube. These screws acting laterally on the brass wire-pointed pin that gave the sun's shadow on the concentric circles, brought it perpendicular over the centre of the plate. A flat small brass ruler was furnished with a socket, which received the point of the shadow-pin. This ruler had a horizontal arm to it, having a semicircle at one extremity coinciding with the tube on the centre of the plate. A pointed wire passed to the plate through the other extremity of the horizontal arm. This wire could be raised or lowered at pleasure by a small screw. It is evident that if this point touched, *delicately*, the plate of brass, in moving it round (by means of the socket above, and semicircle playing round the tube below), the shadow-pin must be perpendicular. If the plate was acted upon evidently *roughly* by the pin in moving horizontally, it is clear the pin must be inclined to that side, and a delicate correction was given by the little brass screws fixed to the tube screwed on the centre. By this contrivance the shadow-pin was fixed exactly perpendicular to the plate.

The box in which the magnet is suspended seems to have come out of the maker's hand unfinished, having on it no hairs through, or parallel to its axis, by which to apply it truly to a meridian. These hairs were fixed above and below the magnet, in a plane perpendicular to the graduated 0° at both ends. Two very fine brass wires were fixed on the outside, on the ends of the box. These brass wires were in the plane of the hairs, and when applied to the meridian, the hairs

appeared to cover the meridian, through circular holes in the bottom of the box. I may venture to assert that the meridian was laid off within one minute of a degree, as it bisected the chords of 12 different arcs of concentric circles made use of. I may also say that the axis, or 0° line of the box, was applied to the meridian within one minute of true position. In laying off the meridian, the operations of two successive days perfectly agreed.—W. or E. put over each observation, indicates west or east variation. As bad weather may prevent observing at the specified hours at the heads of the columns, the hour, if different from 7 A. M. 12 or 5 P. M. or from others at the heads of columns, will be marked over those particular observations.

N. B. In the weather columns, to save trouble, F. means fair, A. after, R. rainy, N. night, L. lightning, C. cloudy, S. sky, T. thunder, m. much, O. overcast, s. serene, W. windy, l. little.

1794	Time. 7 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 5 P.M.	Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	E. 6	°	E.	°	E.	°			
June 27	1 8	74	1 10	81	1 12	81	F. A. a R. N. C.	a north-west wind	R. O. and W.
28	1 8	78	1 10	78	1 12	80	m. R. in the N. and some L.	C. sun at intervals	a l. C.
29	8 1 8	76	8½ 1 10	83½	1 11	82	C. - -	s. sunshine	C. and sultry
July 1	1 7	76	1 11	84	1 11	82	s. sunshine	west wind, sunshine	s. wind north-west
2	1 9	76	1 10	82	1 12	82½	a clear morning	s. sunshine	s.
3	1 9	78	1 11	82½	1 9	82	a clear morning	s. ditto, wind west	s.
4	1 9	74½	1 7	82	1 8	82	a l. C.	s. sunshine	a l. C.
5	1 6	76	1 7	81½	1 10	82	s. - -	s. ditto - -	s. and sunshine
6	1 9	76	1 11	82	1 12	81½	C. - -	s. sunshine	C. R. and distant T.
7	1 9	76	-	-	1 10	81	C. - -	- -	s. sunshine
8	1 9	77	1 10	82	1 10	82	a l. C. - -	s. sunshine	s. ditto
9	1 6	78	1 9	82	1 10	82	a s. S. - -	s. ditto -	s. ditto
10	1 6	75	1 10	81½	1 10½	83	a s. S. - -	s. ditto - -	s. ditto
11	1 9	76	1 9	82	1 10	84	C. and O.	s. ditto - -	s. ditto
full moon. 12	1 9	76	1 10	82½	1 8	83½	a s. S. - -	s. ditto -	s. ditto
13	1 9	75	1 10	83½	-	-	a s. S. - -	s. ditto	
14	1 9	78½	1 10	83½	1 8	84½	a clear morning	s. ditto -	s. ditto
15	1 9	79	1 9	84	1 9	84	a ditto - -	ditto - -	s. ditto
16	1 9	74½	1 8	83	-	-	a calm clear morning	s. ditto	
18	1 8	76	1 9	82	1 10	81	C. - -	s. ditto -	distant thunder, C.
19	1 9	73½	1 10	83	1 9	82	s. sunshine -	a l. C. - -	R. A. T.
21	1 8	79	1 9	83	-	-	s. south-east wind	C.	
22	1 9	74	1 11	77	1 10	79	C. and R. -	C. and R. -	C.
23	1 9	76	1 9	83	1 9	80	C. - -	s. sunshine	C. and R.
24	1 9	74	1 9	82	-	-	s. sunshine -	s. ditto -	
25	1 9	75½	1 10	83	-	-	s. ditto - -	s. ditto -	
new moon. 26	8 1 9	77	1 7	84	1 9	84½	s. ditto -	s. ditto -	s. sunshine
27	1 8	74½	1 10	84	1 9	83½	s. ditto - -	s. ditto - -	s. ditto
28	1 8	75½	1 10	83	1 8	82½	C. - -	s. ditto -	s. ditto
30	1 9	72½	-	-	-	-	s. sunshine		
31	-	-	1 9	82	1 8	82	- - -	s. ditto - -	s. ditto

1794.	Time. 8 A.M.	Time. 12.	Time. 4 P.M.	Thermometer.	Ditto, 2d observation.	Ditto, 3d observation.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	° ′	° ′	° ′	°	°	°			
	E.	E.	E.						
Aug. 1	1 7	1 8	1 9	77½	84	82	s. sunshine	s. sunshine	C. Thunder
2	1 8	-	-	77½	-	-	s. ditto -		
3	1 6	1 8	1 9	79	82½	82	s. ditto - -	s. ditto -	C.
4	1 7	1 8	-	-	82	-	s. ditto -	s. ditto -	
6	1 7	1 8	1 7	78	83½	83	s. ditto -	s. ditto -	C. Thunder
7	1 8	1 8	1 8	80	82	81	s. ditto - -	s. ditto - -	R. C. and distant T.
8	1 8	1 8	1 8	75	77	78½	C. A. m. R. in the N.	C. and O. -	C.
9	1 8	1 6	1 8	76	82	82	s. sunshine	s. sunshine -	s. sunshine
10	1 6	1 6	-	76	82	-	C. - -	s. ditto -	s. ditto
12	1 6	1 6	1 9	78	82	82	s. sunshine	C. - -	C. and T.
13	1 8	1 6	1 9	78	82	82	s. ditto - -	distant Thunder	C. R. and T.
15	1 7	1 7	1 10	79	81	81	s. ditto - -	s. sunshine -	R. and C.
16	1 8	1 8	1 7	77	81	79	C. - -	s. ditto -	m. R.
18	1 8	1 9	1 8	78	81½	80	C. - -	C. - -	C. and high wind
20	1 9	1 6	1 8	77½	80	82	C. - -	C. a l. - -	s. sunshine
21	1 8	1 7	1 9	78	83	83	s. sunshine -	s. sunshine -	s. ditto
22	1 7	1 8	1 10	76	78	78½	C. and R. -	C. R. -	C.
23	1 8	1 6	1 9	76	80	78½	C. -	C. a l. - -	s. sunshine
25	1 7	1 7	-	77	81½	-	s. sunshine -	s. sunshine -	C. distant T.
30	1 7	1 8	1 9	76	82	81	a l. C. - -	s. ditto -	C. distant T.
31	1 8	1 6	1 8	77	82	79½	F. A. R. -	C. - -	s. A. R.

N. B. It was, from forgetfulness, omitted to take and insert the thermometrical observation which should have been attached to the morning variation of the 4th. It is, however, a matter of little consequence in the general consideration of the subject.

1794.	Time. 9 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 3 P.M.	Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	° ′	°	° ′	°	° ′	°			
	E.		E.		E.				
October 1	1 8	80	- -	-	1 9	80½	s. sunshine	R. A. C. S.	
2	1 6	77	1 8	82	1 8	83	s. A. R. -	A. l. C. -	s. sunshine
4	1 6	78	1 9	82	-	-	s. sunshine	s. sunshine	
5	1 6	80	- -	-	1 8	84	a l. C. -	- -	ditto
8	1 6	78	1 10	83½	1 10	84	s. sunshine	s. sunshine	s. ditto
9	1 6	79	- -	-	-	-	ditto		
10	1 6	78	1 9	81	1 10	83½	C. - -	s. ditto -	distant T. sunshine
	10								
12	1 6	79	1 8	82½	1 9	82½	s. sunshine	s. ditto -	C. distant T.
14	1 8	79	- -	-	-	-	s. ditto		
15	- -	-	1 8	82½	-	-	- -	s. ditto	
16	1 7	80	1 7	83	1 7	84	a l. W. -	s. ditto -	sunshine and W.
17	1 6	79½	1 7	83	1 9	84	s. sunshine	a l. C. -	ditto s.
18	1 5	78	1 8	81½	1 8	80½	C. - -	s. sunshine	C.
20	- -	-	1 10	83	-	-	- -	s. ditto	
	10								
21	1 8	80	1 9	84½	1 10	85	s. sunshine	s. ditto -	distant T. s.
22	1 6	78	1 8	84	-	-	s. ditto -	s. ditto a l. W.	
23	1 5	77½	1 9	83	1 9	83	F. A. R. -	s. ditto a l. W.	s. sunshine a l. W.
					4				
24	1 5	79	- -	-	1 8	82	F. C. - -	- -	a l. C. F.
25	1 4	78	1 9	81	1 9	80½	a l. C. A. R.	W. and C.	W. and C.
27	1 5	77½	1 7	79	1 7	78	C. and W. A. m. R.	C. and W.	C. W. very rainy
28	1 4	78	1 8	80	1 9	80½	a l. C. A. m. R.	C. - -	F. s. sunshine
29	1 5	78½	1 9	81	1 9	81	C. and W.	C. and W.	C. and W.
30	1 8	79½	1 9	79½	1 10	79½	a l. C. -	ditto -	a l. C. s.
31	1 4	78½	1 8	82	1 8	82	a l. C. -	s. sunshine	s. sunshine
Novem. 1	1 5	78	1 11	82½	1 9	82½	s. but C. -	a l. W. sunshine	a l. W. sunshine
3	1 8	78	1 10	83	1 10	84	s. sunshine	s. ditto	s. sunshine
4	1 7	79	- -	-	1 11	83½	s. ditto -	- -	s. sunshine
8	1 4	79	1 9	82	1 9	79	s. a l. C. -	sunshine a l. W.	s. but C.
10	1 6	78½	- -	-	1 9	84	s. sunshine	- -	s. sunshine
11	1 6	78	1 12	82	1 8	83½	F. A. m. R. and T.	s. a l. C. -	C. and distant T.
12	1 6	77	1 9	84	-	-	sunshine a l. W.	a l. C. distant T.	
14	1 5	78	1 10	85	1 11	81	s. sunshine	sunshine W. and T.	R. C. and distant T.
15	1 4	76½	1 9	82½	1 10	83	s. but C. -	sunshine a l. W.	s. sunshine
17	1 5	79	1 10	83½	1 9	81	a l. C. -	s. sunshine	C. A. R. with T.
19	1 7	78½	1 7	82	1 9	81½	s. sunshine	At 5 min. before 11 a very violent earthquake—d°	s. but C.
21	1 7	77½	- -	-	1 11	82½	s. sunshine	s. sunshine	s. sunshine
22	1 5	76	1 8	81½	1 8	82	a l. C. A. m. R.	a l. W. -	s. ditto
Decem. 5	1 4	77½	1 9	82½	1 9	82	s. and F. A. m. R.	a l. W. -	sunshine a. l. W.
10	1 6	77	1 7	80	1 8	81	F. A. m. R.	C. and rainy	a l. C. and W.

1795.	Time. 7 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 5 P.M.	Thermometer.	Various Hours.		Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.	4th Observation. Weather.
	° ′		° ′		° ′			° ′					
	E.	°	E.	°	E.	°		E.	°				
Jan. 17	1 6	77½	1 8	82	1 7	78	- -	-	-	C. A. R.	C. strong west wind	C. A. and T.	
19	1 6	78	1 10	84	-	-	-	-	-	s. sunshine	s. distant T.		
20	-	-	1 10	83½	-	-	-	-	-	-	s. sunshine		
21	1 6	77½	1 12	82½	1 9	81½	2 P. M.	1 10	82½	a l. C. s.	s. sunshine	s. a l. C.	distant T.
22	-	-	1 10	78½	-	-	10 A. M.	1 8	76	-	C.	-	C. A. m. R. in the N.
23	-	-	1 10	79	1 9	79	2 P. M.	1 10	76½	-	s. a l. C.	s. a l. sunshine	C. a high north-west wind
24	1 6	75½	1 10	81½	1 10	82	-	-	-	s. sunshine	s. sunshine	s. sunshine	
26	1 7	77	1 9	81	-	-	2 P. M.	1 10	82	a l. C. s.	s. sunshine	-	s. sunshine
28	1 5	74	1 8	77	1 7	75	9 A. M.	1 6	75	C. A. m. R.	C. with R.	C. a l. R.	C. A. m. R.
29	1 8	73	1 9	81	-	-	12 P. M.	1 8	77	s. sunshine	a l. C.	-	a fine N.
30	1 7	74	1 9	81	1 9	82	11 P. M.	1 8	78	s. sunshine	s. a l. C.	S. a l. C.	a fine s. N.
31	-	-	1 8	82	-	-	-	-	-	-	s. sunshine		
Febr. 8	A.M.				4 P.M.								
2	-	-	1 10	84	-	-	-	-	-	sunshine, a l. W.			
3	-	-	-	-	-	-	10 P. M.	1 7	78¼	-	-	-	a fine N.
4	1 6	75½	1 8	79½	-	-	11 P. M.	1 7	76½	s. a l. C.	s. a l. C.	-	a s. fine N.
5	1 5	76	1 10	84	-	-	10 P. M.	1 9	82	s. a l. C.	sunshine, a l. W.	-	a s. fine N.
6	1 6	78	1 9	84	1 10	84½	12 P. M.	1 7	80	F. a l. W.	a l. W.	s. sunshine	a s. fine N.
7	1 6	78	-	-	-	-	11 P. M.	1 7	79	a strong wind	-	-	a fine N.
8	1 7	79	1 11	82½	-	-	-	-	-	s. and mild	very W.		
9	1 7	79	1 11	82	1 11	82½	11 P. M.	1 8	78	s. sunshine	a l. W.	a l. R. and C.	a C. N.
10	1 8	77½	1 7	82	1 9	84½	-	-	-	s. sunshine	s. sunshine	s. a l. C.	
11	1 7	77	1 10	84	-	-	11½ P. M.	1 9	79½	s. sunshine	distant T.	-	a s. fine N.
12	1 6	76	1 8	82	1 11	84½	10 P. M.	1 7	79	s. -	s. sunshine	s. sunshine, and distant T.	a C. N.
13	1 7	78	1 8	84½	1 8	79	-	-	-	s. sunshine	distant T.	R. and T.	
14	- 6	-	1 10	82½	1 10	81½	10 P. M.	1 9	78	-	loud T. C.	s. and C.	a s. C. N.
16	1 8	76	1 8	83	1 8	84½	7 P. M.	1 10	80	s. A. m. T.	a C. S.	distant T.	heavy near T. & L.
17	1 7	78	1 8	83	1 10	84½	11 P. M.	1 9	80	s. sunshine	s. sunshine	s. sunshine	a s. C. N.
22	-	-	-	-	-	-	2 P. M.	1 11	84½	-	-	-	s. sunshine
23	1 9	78	-	-	-	-	1 P. M.	1 10	84½	s. sunshine	-	-	c. ditto
26	-	-	-	-	-	-	3 P. M.	1 9	76	-	-	-	a C. N.
27	1 10	77	-	-	1 11	84	-	-	-	s. sunshine	-	s. sunshine	
28	1 9	79	1 11	84	1 11	83½	-	-	-	s. ditto	a l. W.	distant T.	
Mar. 11	1 6	79	1 8	83	1 10	80	11 P. M.	1 8	77	a high wind	a high wind	a high wind	a C. N. A. R.
12	1 6	78	1 8	80	-	-	11½ P. M.	1 8	76½	C. and W.	C. R. and W.	-	a l. R. and C.
13	1 6	77	1 10	82	1 9	81	12 P. M.	1 8	78½	a l. C. A. R. N.	s. sunshine	s. a l. C.	a s. N.
14	1 6	79	1 10	83	1 10	82	12 P. M.	1 8	79	s. sunshine	s. a l. C.	s. and C.	a R. N.
16	1 6	78	1 9	84	1 10	82	12½ P. M.	1 9	79	s. ditto	s. sunshine	s. and C.	C. distant T.
17	1 6	79	1 9	84	1 10	83	11 P. M.	1 8	79	s. ditto	s. ditto	s. a l. C.	a s. C. N.

XIV. *Particulars of the Discovery of some very singular Balls of Stone, found in the Works of the* Huddersfield *Canal. By Mr.* Benjamin Outram, *Engineer to the* Huddersfield *Canal Company. Communicated by Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read April 21, 1796.

THE Huddersfield canal is to be carried through that chain of mountains which extends from the Peak of Derbyshire, in a northward direction through Yorkshire, &c. into and through a great part of Scotland, by pursuing from the navigation at Huddersfield a deep and narrow valley to Marsden, where it enters the north-eastern foot of one of these mountains, called Pule Hill, under which it is to be extended south-westwardly by a subterraneous cut or tunnel to the foot of Stand Edge Hill, or Brunn Clough, where it again excavates; and pursuing the bottom of a deep valley into Saddleworth, passes along the banks of the Tame to Ashton-under-Lyne, where it joins the canals that extend to Manchester, Stockport, Peak Forest, &c.

In the latter end of the year 1794, the miners employed by the canal company began to perforate the north-eastern foot at Pule Hill; the strata they first cut through consisted of a greyish coloured shale, the beds or laminæ of which did not lie quite horizontal, but dipped or inclined a little to the westward. The strata continued regular till the workmen had

perforated about 240 yards in length from the entrance of the hill, and were about eighty yards deep from the surface of the ground immediately over them, when they discovered on the north side of their work a *fault*, *throw*, or *break* of the strata, which was filled with shale, reared on the edge, and mixed with softer earth, and in some places with small lumps of coal. In continuing to pursue the direction of the tunnel, this fault occupied by degrees more of the space of the tunnel, for about forty yards in length, when it nearly occupied the whole tunnel, which is near four yards in width; and at about five feet from its southern margin it contained a rib of limestone, near four feet thick in the bottom, but not quite so thick at the top of the tunnel; and on each side this rib it contained balls of limestone promiscuously scattered, and of various sizes, from one ounce to upwards of 100lbs. weight.

The rib and balls of limestone were first found at about 280 yards from the north-eastwardly end of the tunnel, where it is about 90 yards in perpendicular depth from the surface; and the workmen have now pursued the tunnel to near 350 yards from the entrance, and the rib of limestone and balls continue nearly the same; the rib has varied a little in thickness, and has not pursued a straight line; it in one place nearly left the tunnel to the northward, but in a few yards turned southward, to its former direction. The limestone of the rib is not perfectly pure, that in the balls is still less so, but it makes a good lime for cement. The balls when broken appear to be mixed with a kind of pyrites, in small particles, near their outward edges; their form is very peculiar, being similar in all their sizes; it is not perfectly globular, being flattened a little on two opposite sides, which appear to have been

the poles when in a revolving state; and each ball is more or less furrowed in a latitudinal direction, as if, when revolving round its axis, and taking its *fixed* from a more *fluid state*, it had met with some resisting substance.

Though the surface of this country is very rocky, it does not discover limestone any where within 20 miles of this tunnel; yet if the strata near the limestone at Buxton to the south, and at Clitheroe to the north, are examined, it will appear probable that the base of these hills is limestone at *some depth*, and this *fault* discovered in the shale probably extends from the limestone bed beneath; and the rib of limestone and balls, which, with other mixed substances, fill up this crevice or fault, were probably thrown thither from the mass beneath, by the volcanic eruption which first occasioned this *break* in the strata, or by some subsequent eruption of the same kind.

XV. *Account of the Earthquake felt in various Parts of* England, *November* 18, 1795; *with some Observations thereon. By* Edward Whitaker Gray, *M. D. F. R. S.*

Read May 12, 1796.

HAVING been desired by the President of the Royal Society to draw up, from various letters transmitted to him and to the Society, and from such other authentic information as I might be able to procure, an account of the earthquake which was felt in most of the midland counties of England, on Wednesday, November 18, 1795, I beg leave to lay before the Society the following account thereof; which, however imperfect it may be, contains all the material information I have been able to obtain upon the subject.

The earthquake happened, as is already said, on Wednesday, November 18, about eleven o'clock at night. The state of the weather, and other circumstances previous to it, are described in some of the letters hereafter noticed. Before I proceed to take notice of them, I shall endeavour to give a general idea of its extent.

It appears that the shock was felt as far to the north as Leeds, and as far to the south as Bristol. To the east it was felt as far as Norwich, and to the west as far as Liverpool. Its extent from north to south, therefore, was about 165 miles;

and its extent from east to west about 175. In this latter direction, or rather from north-east to south-west, it may be said to have reached nearly across the island.

The counties in which I have any account of the earthquake having been perceived are Somersetshire, Wiltshire, Oxfordshire, Buckinghamshire, Northamptonshire, Huntingdonshire, Norfolk, Lincolnshire, Leicestershire, Warwickshire, Gloucestershire, Herefordshire, Worcestershire, Staffordshire, Cheshire, Derbyshire, Nottinghamshire, Yorkshire, and Lancashire.

To those counties may, I think, be safely added Rutlandshire, Berkshire, Bedfordshire, Cambridgeshire, and Shropshire. I have not indeed met with any account of the earthquake from either of them; but, whoever will examine the situation of these counties, with respect to those above enumerated, will find it difficult to conceive that they were not, in some degree, affected by it."*

Perhaps a general idea of the extent of the earthquake cannot be better obtained, than by supposing the four places already mentioned as its extreme points, namely, Bristol, Liverpool, Leeds, and Norwich, to be joined by right lines, so as to form a quadrangle. That quadrangle will comprise, as accurately as such a figure can be expected to do, the parts to which it may reasonably be presumed to have extended.

Respecting the effects of the earthquake in many of the counties abovementioned, I have not been able to collect any particulars which appear to me worth relating; with regard

* I know it has been said that earthquakes have been felt at two places distant from each other, and not at an intermediate place; but I see no sufficient reason for supposing that to have been the case in the present instance.

to such counties, therefore, I think it unnecessary to do any thing more than to record its having reached them. And, for such record, I have, in some instances, considered the newspapers of the respective counties, or some such public testimony, as sufficient authority; provided the situation of the place where the earthquake was said to have been felt was such as to come within the general outline of its extent.

I shall now proceed to those details respecting the earthquake which have been received from various counties; taking them in the order in which those counties are mentioned above.

From Belton, the seat of Lord BROWNLOW, in Lincolnshire, the following account was sent by Mr. CHRISTOPHER DRIFFIELD, in a letter dated November 19.

"We had yesterday a most violent hurricane of wind, which "began about eight o'clock in the morning, and continued "till about one. After the wind settled we had a heavy rain, "which ceased about four in the afternoon, and it was a very "fine evening; but, about eleven o'clock, as near as I can say, "we felt a terrible shock of an earthquake, which lasted about "two seconds. It shook the chair in which I was sitting, be-"ginning with a violent rumbling, or noise, as if some large "carriage had run against the gate-post. It went from north "to south. It was generally felt at Grantham, and in this "neighbourhood."

The following account of its effects in Leicestershire, is given in a letter from Mr. WILLIAM KING, dated Belvoir castle, November 30.

"The earthquake happened, as near as I can collect, about "5 or 10 minutes after eleven in the evening. The wind

" during the day had been very brisk, but towards the even-
" ing (6 o'clock) it became almost totally calm, and continued
" so the whole night. The shock was strong enough at the
" castle to waken those who were asleep. Some, though but
" few, thought it was an earthquake; the general opinion was
" that something had fallen down in the room over head; or
" had struck the floor underneath; or that an adjoining par-
" tition or door had received a blow. Pendulous bodies were
" put in motion, as well as some doors that were not shut.
" Instances of both these happened in the castle, and they,
" in some measure, confirm an opinion that the shock was un-
" dulatory. It happened at a time when few were out of doors,
" but some were, and they all agree that the shock was not
" attended with any extraordinary light; neither was there
" any ball of fire, nor any singular motion, in the air.

" The Rev. Mr. PETERS, whose residence is at Knipton, a
" mile and a half from the castle, gives the following account.
" He was going to bed, but, at the instant, stood with his
" back against a wall; he found the whole room shake, par-
" ticularly the bed curtains. As he had felt many earthquakes
" in Italy, he immediately knew it to be one, and was atten-
" tive to the consequences. He declares that the air was calm
" at the time; had no noise in it; nor did he perceive any ex-
" traordinary light. Knipton is in a low situation, and was
" shaken as much as the castle."

Of its effects at Kenilworth, in Warwickshire, the following description is given by ROBERT AUGUSTUS JOHNSON, Esq. F. R. S. in a letter dated November 25.

" The earthquake was felt at Kenilworth about twenty mi-
" nutes after eleven; but our common clocks are usually kept

" with the sun, and were therefore, at that time, nearly a
" quarter of an hour too fast; by true time, I reckon it to
" have been six minutes past eleven. I had lain down some
" little time, when I felt the bed raised up. My first idea was
" that a large dog had got under it, but the immediate shak-
" ing of the curtains, and of the room, convinced me this
" could not be the case. All those who were in bed, and
" awake at the time, describe it in the same way; every one
" supposing that their beds were raised up by some living
" creature under them. It was not so universally felt by per-
" sons who were up; those who were engaged in conversation
" did not, in general, perceive it; but, of those whose attention
" was less occupied, some felt their seats slipping from under
" them, others saw things move which were hung up, and
" some heard the doors and windows rattle. Many say it was
" attended with a low rumbling noise, but this I did not hear.
" The motion, as well as I can judge, continued nearly two
" seconds. The evening was perfectly calm, after a most tem-
" pestuous night and day, with the wind nearly south-west.
" The barometer, for thirty-six hours preceding, had varied
" very remarkably. On Tuesday morning, the 17th, it stood
" at 30.23, but sunk gradually, during the course of that day,
" and more rapidly in the night: to the best of my recollec-
" tion, it was on Wednesday morning at 28.63, and that night,
" a little before the shock was felt, at 28.8. The thermometer,
" in a room without a fire, was about 48 or 49° the whole
" day. I am not able to state the degree of moisture in the
" air, (my hygrometer being broken,) but it was loaded with
" humidity, making the passage walls and floors damp. The
" effects of the earthquake were most sensibly felt on the tops

" of hills, or on high ground; but I have not heard of its " having done any damage in this country."

From Worcester the following account of it was sent by Dr. Johnstone of that city, in a letter dated November 24.

" The earthquake was chiefly felt by persons in bed, about " eleven o'clock, or five minutes after, who describe the sen- " sation to have been as if some person under the bed had " heaved it up. That sensation was preceded, the instant be- " fore, by a noise which some call rumbling, and which others " compare to the falling of tiles, though none fell from the " houses where they lived. Many persons heard the windows " and doors of their rooms rattle at the same time, which in- " creased their alarm. Thunder and lightning had been ob- " served some days before; and several persons, of a delicate " state of health, passed the night of the 18th in a restless " uneasy manner, without knowing why, though very much " in the manner in which they used to be affected by thunder " and lightning."

In Derbyshire the shock appears to have been very severe. A description of its effects, not only upon the earth, but also under its surface, is contained in the two following letters from Mr. William Milnes, of Ashover: the first is dated November 20.

" On Wednesday night, about a quarter past eleven o'clock, " a severe shock of an earthquake was felt here. I felt it very " sensibly; at first I heard a rumbling kind of noise, and im- " mediately after it appeared as if some person or persons had " violently forced into the room; the bed, and every thing " else, shaking very much. The workmen in Gregory mine

" were so much alarmed by the noise, and the sudden gust of " wind that attended it, as to leave their work; some expect- " ing that the whole mass of *bunnings* above them, which " contains many hundred tons weight of rubbish, had given " way, and that they should be buried in the ruins; others, " who were at work near the new shaft, supposed that the " curb which supports the walling had given way, and the " whole shaft had run in. Several chimnies were thrown " down, and several families left their habitations; indeed " such a general alarm was never known in this neighbour- " hood."

The gust of wind mentioned by Mr. MILNES being considered as a remarkable circumstance, he was desired to make some farther inquiry concerning it: in consequence of which a second letter was received from him, dated December 4, as follows:

" I have examined all our miners separately, and, from the " following circumstances, I think there cannot be a doubt " but the wind which was felt in the mines, on the 18th of last " month, rushed into the shafts from the surface.

" Those men who were at work in the pumps, which are " a considerable depth below the waggon gates, and have " no communication therewith, did not feel the wind; but " heard, in the first place, a rushing rumbling kind of noise, " which appeared to be at a distance, and to come nearer and " nearer, until it seemed to pass over them, and die away. " Those who were in the waggon gate which has a commu- " nication with the engine shaft, and the new shaft, felt a " very strong current of wind; which, one man says, conti- " nued whilst he walked about six or seven yards, and came

" along the gate, as if it came from the new shaft; he had no " light, but, as he went along the gate, the sides thereof, " where he laid his hands, felt as if they were going to close " in upon him.

" The only one who saw any appearance of light, on that " evening, in this neighbourhood, (that I have been able to " make out,) was a person who lives with Mr. ENOCH STE- " VENSON, the miller, at Mill Town. He informs me that, as " he and another man were returning from Tideswell, he saw, " when he got upon a piece of high land near Moor-hall, on " the road to Chatsworth, an uncommon light; and, when " looking towards Chesterfield, the sky appeared to be open " for about the length of a mile, the colour pale red, and con- " tinued so while he awakened his fellow servant, who was " asleep in the waggon, to shew him (as he described it) the " strangest flash of lightning that ever was seen. From his de- " scription, the range of it was from east to west; and so low " in the horizon that, had he not been upon high ground, he " could not have seen it."

From Wirksworth, in the same county, (Derbyshire,) two letters respecting the earthquake were received from the Rev. ABRAHAM BENNET, F. R. S. of which here follow extracts. The first letter is dated November 19.

" About twenty minutes past eleven o'clock last night, the " shock of an earthquake was perceived in this town, and, as " I have been informed, at Derby, Ashover, Bakewell, Win- " ster, and other neighbouring villages. I happened to be in " bed at the time, and was awakened by a noise, which I first " supposed to be like the roaring of a chimney on fire, then " thought it was a carriage in the street, and should not have

"suspected an earthquake; but this morning I was told that "many persons had been much alarmed, said they heard a "noise resembling the falling of a chimney, and went out to "examine whether that was the case. A person just arrived "from Derby says, that a ball of fire was seen to pass over "the town, at the time the noise was heard. Many said their "beds shook, and that they felt something like an electrical "shock. At Derby some bricks were thrown down from "chimnies. The noise was also described as resembling the "drawing of a table over a floor, with a louder explosion at "the last.

"The wind had blown violently from the south-west all "day, but became calm in the evening, and the sky cleared. "At the time the earthquake happened it was remarked that "the air became very cold; and this morning the ground was "covered with snow; which now melts, and the wind is "changed to the north-east.

"These circumstances seem to favour the supposition of "earthquakes being caused by electricity; but it is only from "a collection of numerous facts, that any rational theory can "be formed on the subject."

In his second letter, dated December 21, Mr. BENNET says; "I have been at Derby, and made inquiry about the ball of "fire said to have been seen there, but could obtain no ac- "count of any thing more than that several persons, who hap- "pened to be out, perceived a flash of light, which they de- "scribed as being like an opening of the sky. I had written "to Mr. CHATTERTON to make every inquiry he could, but he "heard nothing more than this, besides what was observed by "others. I wrote also to Mr. WATSON, of Bakewell, who says

" he had been in bed about a quarter of an hour, when he was " astonished by a hushing rumbling noise, and was immedi- " ately shook in bed, by a lifting up, of first his head, and " then his feet, three times in about three seconds; his bed " standing south and north, he thought it came from the south. " At an inn there the servants were frightened by the glasses " shaking upon a table; some gentlemen, in another room, " felt nothing of it. One person at Bakewell observed a flash " of light like lightning; and Mr. BUXTON's house, (at Bake- " well,) which stands upon a limestone rock, was shook till " his bell rung.

" The Rev. Mr. PEACH, of Edensor, was shook in bed, and " heard a noise in his room, like the collision of two stones.

" At Chesterfield some chimnies fell."

The county of Nottingham, however, appears to have been that in which the earthquake was most severely felt. From that county two very circumstantial accounts of it have been received; one of them from the Rev. EDWARD GREGORY, in a letter dated Langar, December 12, as follows.

" I was, on the 18th of November, at Wollaton, (the seat " of Lord MIDDLETON,) about three miles to the west of Not- " tingham, where I felt the shock of the earthquake. A vio- " lent gale of wind, which blew from the south-west, raged " with uncommon fury all the morning, and brought on heavy " rain about noon; the storm still continuing with unabated " violence. About three o'clock the wind changed to north- " west, and the tempest presently subsided. The clouds now " separated, and formed themselves, on the northern quarters of " the horizon, into those very large white mountainous clouds " which, in the summer months, generally precede a thunder

" storm. About sunset these clouds were very much dis-
" persed; the air became clear, felt sharp and elastic, and
" every appearance of a frost came on in the northern parts of
" the sky. When the company assembled in the south draw-
" ing-room, previous to dinner, my attention was much struck
" with the aspect of the sky in the south and south-east quar-
" ter; in this direction, a cloud, very black and lowering, ex-
" tended itself over this part of the hemisphere. The margin
" of the cloud, which was nearly parallel to the horizon, was
" fringed, to the extent of at least forty degrees, from the south
" towards the east, and to the breadth of perhaps a degree and
" a half, with a very bright white light, which had very much
" the appearance of white satin. This light was shaded, to its
" whole extent, as it were with a veil of a deep muddy purple
" colour. The white light, seen below this gloomy purple
" haze, and farther contrasted by the very dark surface of so
" extensive and lowering a cloud, formed a very striking ap-
" pearance; so much so as to induce me to call Lord Mid-
" dleton, and others of the company, to the window, to look
" at it, and to remark to them, that the very angry and trou-
" bled aspect of the sky led me to apprehend we should have
" more of the tempest in the course of the night. I will here
" remark that it was now near five o'clock; the sun was gone
" down too low to cast any considerable degree of light on
" the clouds near the western horizon, much less could he il-
" luminate any cloud so low in the south-east as this was with
" so bright a light. The moon, indeed, was near the western
" extremity of this cloud; but its light, even had it been a
" full moon, (whereas it yet wanted more than twenty-four
" hours of being in the first quarter,) was far too weak to cast

" on the margin of the cloud so intense a light, and that to
" so great an extent along it. For these reasons, I was fully
" persuaded that this luminous appearance was occasioned by
" electric light, with which I concluded the cloud to be highly
" charged. We went down stairs to dine, and returned again
" to this room about eight o'clock, to pass the evening; I then
" looked again at the sky; every extraordinary appearance
" had now vanished, the night was dark and gloomy, the air
" quite calm and mild. At between twenty and twenty-five
" minutes after eleven o'clock, we were all extremely sur-
" prised and alarmed at a sudden blast, (so I should term it,
" rather than explosion, because it had not that sharp, com-
" pressed elastic tone I annex to the idea of an explosion,)
" which burst out instantaneously, somewhat below the ze-
" nith, to the west; and, as I conjectured from the direction
" in which the sound was heard, seemed to rush through the
" air towards the east with great velocity, and to meet with
" considerable resistance to its motion; for it made a whiz-
" zing noise as it passed over us. At the instant the blast
" burst out, it was accompanied with a very loud, deep-toned,
" hollow, sullen sound, not altogether unlike a deep groan.
" We were all amazed at this hideous noise; some thought
" the window of the great room (that in the centre tower over
" the hall) had fallen in: every one of us thought some bad
" accident must have happened to some part of the building.
" While we were all forming our various conjectures, I, who
" sat close to the wall, (a north wall,) leaning with my arm
" and shoulder on the surbase, felt myself shoved from it, and
" my chair shaken under me, with a very quick tremulous
" motion. All the company (eight or ten) felt the same

" sensation from the shock; which was so forcible, that some " thought I had fallen from my chair on the floor, and had oc- " casioned the concussion they felt; when they saw this was " not the case, they then imagined the servants in the dining " room below us, in removing the tables, had thrown down " one of them. When I felt the wall shake, I had no doubt it " was an earthquake, and I told the company so; but that it " was now over, and we were all safe, and had no reason to be " farther alarmed. I had scarcely uttered these words, when " we were shaken again. This second shock was more undu- " latory than the first; at this time I was standing, and felt " myself lifted up a little, as the shock passed along. We were " all now under great apprehensions, lest other and more vio- " lent shocks might succeed those we had already felt; but " after a few minutes had elapsed, without our perceiving any " thing more, our alarm subsided. Such of the company as " had withdrawn returned to us, to inquire what could be the " cause of the strange noise, and the shocks which succeeded " it; not being yet aware that it was an earthquake. I have " already mentioned the time the blast was heard; the first " shock of the earthquake came on, as near as I can guess, " about a minute after it; and the second shock succeeded the " first at the interval of twenty seconds. I went down to the " steward's room, and servants' hall, to inquire what was felt " of the earthquake, and whether they saw any light at the " time they heard the blast. They said they saw no light " whatever, but that the shock caused the glasses to dance " upon the table, in such a manner that they imagined some- " body was drumming under the table with their knees. I " then went into the garden, to look at the sky; it continued

" much as it was at eight o'clock, dark and gloomy, without
" any particular appearance; the air was quite calm, and mild.
" When I got up in the morning, I was surprised to see the
" country covered with snow; the trees in the park were
" loaded with it; I believe no morning in the last winter
" could have presented more appearance of extreme severe
" weather. My man slept at Nottingham; at the house where
" he was, the earthquake was so violent as to cause the cham-
" ber bells to ring. I inquired of two soldiers belonging to
" the barracks, situated on the high ground in the park near
" that town, what was felt of the earthquake there. They
" told me the shocks were very strong, so much so as to alarm
" them greatly, and to shake the plates off the shelves. I
" farther inquired whether any blaze of light, or ball of fire,
" was seen when they first heard the blast, or during the
" shocks of the earthquake. They said, that no light was seen
" at either of these periods, nor did the centinel on guard per-
" ceive any singular appearance whatever.

" Here, in the vale of Belvoir, most people were in bed, and
" were awakened by the shocks, which they describe to me, as
" raising up the bed, and then shaking it; so that at first they
" thought somebody had hid themselves under the bed, and
" was playing tricks to frighten them; but, when they heard
" the doors rattle violently, the plates on the shelves move,
" glass, china, &c. jar together, they were aware that the cause
" of all this was an earthquake. Very few were awakened by
" the blast, and none I have conversed with saw any meteor,
" or other appearance of light. The shock was so strong at
" Colston Basset (two miles from Langar) as to shake a small
" dog off the bed on which it slept. Bricks, such as were

" most likely ready to fall by the first gust of wind, were shaken " off the chimnies. Some small part of the bank of the canal " near Redmile was thrown back again into the canal; which " is supposed to have been done by the earthquake, the bank " having been in an uninjured state the preceding evening. " Concerning the direction of the shocks, people here do not " accord; this is not to be wondered at, as most of them were " awakened out of their sleep, and could not collect their " thoughts together soon enough to ascertain this circum- " stance. In general, those who were awake, previous to the " shocks, seem confident they came from the north-east, but " many think they came from the south. The first shock felt " to me so tremulous that I could not form any judgment con- " cerning its direction; my chair was shaken with a kind of " vertiginous motion. The second shock seemed to come " from the north, perhaps a few points to the west of it.

" When I heard the blast burst out, and rush on, with a " whizzing noise, through the air, I immediately concluded " that some electric meteor (which, I supposed, took fire " at that time) was the cause which produced that alarming " dismal sound which we heard; and that the concussion in " the atmosphere, being communicated to the earth, had " shaken it with such forcible agitations as to cause the " shocks of the earthquake. The clouds on the preceding " evening, being to all appearance very highly charged with " electric fire, confirmed me in this opinion; yet, as far as " I can ascertain, and I have diligently inquired of various " persons who were out, and in situations where they had " a considerable extent of view, no meteor, nor light what- " ever, was seen hereabouts at any time that night. Those

" in bed (as I have already related) felt themselves lifted up, " and shaken. From this circumstance, one is led to imagine " the cause of the earthquake to have been within the earth; " yet, all the circumstances considered, I incline to think some " violent concussion in the air occasioned it. The blast " (whatever was the cause of it) was undoubtedly in the " air. The very heavy fall of snow during the night seems a " singular circumstance; it might be accidental, yet I feel a " bias to think it so far connected with the cause of the earth- " quake, as to have been the result of a sudden and extraor- " dinary change in the atmosphere, brought about by some " electric agency; and that it was a collateral effect of the " cause (be that cause what it may) which occasioned the " earthquake.

" I have been, since the earthquake, on the eastern side of " Derbyshire; it was felt there very smartly. I remark that " most places in high situations were shaken with more vio- " lence than those in flat countries; for instance, in Derby- " shire; at the barracks near Nottingham; and in the villages " which, in the south direction, bound this vale."

The other account from Nottinghamshire is given by Dr. STORER, in the following letter, dated Nottingham, March 12, 1796.

" On the 18th of November last, at eleven o'clock at night, a " very smart shock of an earthquake was felt in this town and " neighbourhood. It was preceded by a noise, which appeared " to me like that of dancing in the room over that in which " I sat, accompanied by a clattering of the furniture; and " beginning, as seemed to me, at the north-east, and passing " to the south-west corner of the room. To others the reverse

" of this appeared to be the direction; but all who attended " to the circumstance of direction, attribute to it a southerly " and northerly course; and every person, whether within or " out of doors, referred the noise to something above their " own situation. I think the noise continued about three " seconds, and was instantly succeeded by the shock; which " was so considerable and alarming as to give me the idea of " an earthquake, from the moment of its commencement, and " to make me imagine that I saw, as well as felt, an elevation " of the hearth, on which my feet rested as I sat; but which " was not found to be displaced, in respect to surrounding ob- " jects. That the walls of the room suffered a considerable con- " cussion was evident, from the vibration of the window-shut- " ters, pictures, and every other pendulous object in the room.

" I had guessed the duration of the shock itself to be four " seconds; but a friend of mine (who had experienced similar " shocks in Carolina) assured me that, after the first impulse, " he had time to look at his watch, and to count four seconds " before its termination: in his opinion, the duration of the " shock could not be less than five seconds and a half. Such " was the violence of it, that (though no material damage hap- " pened to the buildings) most people in this town and neigh- " bourhood, who were asleep, were awaked; and many so " suddenly and completely as to be conscious of having expe- " rienced an earthquake.

" Nothing connected with this object has surprised me so " much as the extreme disparity of the sensations communi- " cated by the shock to different people, in the same room, " and in all respects similarly circumstanced. Every person

" equally heard the noise, and had their attention awakened " by it; yet some felt the shock in an alarming degree, while " others, at the distance of a few yards, perceived nothing but " the noise, and the rattling of the furniture; a few felt some- " thing like an electrical shock, and nothing else.

" Though there are many mill-ponds, canal reservoirs, and " other considerable pieces of water, in this county, which " would have been liable to untoward accidents from any ma- " terial agitation or elevation of their surfaces, I do not find " that any such thing was observed.

" As it is unusual for workmen to be in the coal mines at " that hour of the night, I have heard of but one instance " where that was the case. In one of the mines there were a " man and a boy; the former felt nothing; the boy, who was " nearer the shaft, perceived a rumbling, which he supposed " to be at the top of the shaft, but felt no shock.

" I have seen few people here who were in the streets, or " without doors, at the moment the earthquake happened, " and of these no one perceived any light in the heavens; but " it is reported that a light was seen by the passengers in " some of the coaches; and a very intelligent gentleman of " Derby told me that, being in the street, he perceived, at " the instant of the concussion, a remarkable coruscation, " proceeding from the south-west quarter of the heavens, " (which he could not then see,) and producing a gleam simi- " lar to a distant flash of lightning, but of longer continuance. " Others, at Derby, saw the same thing through their win- " dows.

" In every direction, to the distance of 25 miles at least

" from this place, the shock was felt with equal force; be-
" yond that distance, my information is too inaccurate to be
" stated here.

" The state of the atmosphere that accompanied this phæ-
" nomenon is scarcely less remarkable than the earthquake
" itself. In the night of the 17th it had blown with some vio-
" lence from the south-west; in the morning the gale increased,
" and at eleven o'clock blew a tempest, accompanied with very
" dark dense clouds, and with a greater degree of warmth, or
" rather sultriness, than I ever recollect to have felt in Novem-
" ber, when there was no sunshine. About mid-day there fell a
" heavy rain, for an hour; after which the wind abated, the
" clouds dispersed, and at six o'clock it was a serene calm even-
" ing. At the moment of the earthquake it was perfectly still,
" and continued so at one o'clock in the morning, with the
" same degree of warmth that had prevailed in the day. At
" eight o'clock the following morning it froze intensely, and
" the ground was covered with snow.

" It being very generally agreed to refer the most formidable
" earthquakes to subterraneous causes, it may be thought un-
" philosophical to search for causes of a different order from
" those that are known to produce similar effects; yet it must
" be admitted, that many circumstances in the preceding ac-
" count conspire to connect the concussion with the very sin-
" gular state of the atmosphere accompanying it, and irre-
" sistibly to direct our inquiries to those sudden revolutions
" to which so vast a mass of elastic and heterogeneous fluid is
" liable."

Having now laid before the Society all the circumstances observed in the late earthquake that appear to me to be wor-

thy of their attention, I shall proceed to make a few observations upon them; and particularly to examine how far it is possible, by tracing the direction of the earthquake, to determine whether it was produced by a central force acting in all directions, or whether, like a blast of wind, it had a progressive motion one way only.

And first I must observe, that all ideas of its direction, founded on the sensations of those who felt it, are so vague and contradictory as to render it impossible to draw any conclusion from them. Mr. GREGORY, who in his letter says the blast came from the west, says also, that people in general seem confident that the shocks came from the north-east, but that many think they came from the south; and that, to himself, the second shock appeared to come from the north. Dr. STORER says the direction appeared to him to be from the north-east to the south-west, but to others it appeared the reverse. The accounts of the earthquake's direction in the county newspapers are as various as the above; but I think it needless to give any farther proofs of what I have advanced, and shall only observe that, various as the opinions of those who felt the earthquake were, with respect to its direction, the greater number of persons agreed in thinking it to have been from some northern point towards a southern one; which, as we shall presently see, is as contrary as possible to that direction which is deduced from observations of the time at which it was felt in different places.

In the county papers, the earthquake is said to have been felt at Bristol, and in some parts of Gloucestershire, some minutes before eleven. At Worcester, it is said (by Dr. JOHNSTONE) to have been felt about eleven, or five minutes after.

At Kenilworth, in Warwickshire, (Mr. JOHNSON,) six minutes after eleven. At Ashover, in Derbyshire, (Mr. MILNES,) about a quarter past eleven. At Wirksworth, in the same county, (Mr. BENNET,) about twenty minutes past eleven. And at Wollaton, in Nottinghamshire, (Mr. GREGORY,) between twenty and twenty-five minutes past eleven.* From this, about five minutes and a half are to be deducted, for the difference of longitude between Bristol and Wollaton. Great allowance must likewise be made for the uncertainties which attend observations of this kind, from the different manner of keeping clocks, and from other circumstances too obvious to be mentioned; but it must be remembered, that those circumstances are as likely to occasion error on one side as on the other; and, when the whole is fairly considered, it seems to me impossible not to feel inclined to think that the earthquake was felt considerably later in the north-east than in the south-west; in other words, that it moved progressively from the south-west to the north-east, or nearly so.

Supposing, however, that some of the abovementioned observations of time are of too uncertain a nature to admit any inference to be drawn from them, others among them are of a very different kind. Mr. JOHNSON, whose accuracy may be safely relied on, appears to have remarked the time of the earthquake with great precision, and he states it to have been, at Kenilworth, at six minutes past eleven. Mr. GREGORY, to whose exactness we may equally trust, says the blast was heard, at Wollaton, between twenty and twenty-five minutes

* I have omitted mentioning the time expressed in one or two of the foregoing letters, because it appears not to have been observed with much attention.

past eleven, and the earthquake came on about a minute after the blast. Now, if we suppose it to have been only twenty-one minutes past eleven when the blast was heard, it will bring the time of the earthquake to twenty-two minutes past eleven; and, if we allow a minute and a half for the difference of longitude between Kenilworth and Wollaton, there will still remain an interval of fourteen minutes and a half for its progress from the first mentioned place to the latter. The distance between these two places is about forty-five miles, and the situation of Wollaton, with respect to Kenilworth, is about north north-east: consequently, the observations of Mr. JOHNSON and Mr. GREGORY are, of themselves, sufficient to render it probable (as far as observations of time made in two places only can do so) that the direction of the earthquake was not very different from that above stated; at least, that it was from some point to the westward of south, towards some point to the eastward of north; which, as was before observed, is very contrary to the idea which most persons who felt it formed of its progress.

These two observations also, in my opinion, furnish another argument that the earthquake moved progressively in one direction only; for, if it had been produced by a central force acting in all directions, we should surely have expected that the effects of that force would have been most powerful where they were first felt; whereas, we have seen that the earthquake, though undoubtedly more severe in Nottinghamshire than in Warwickshire, was felt much sooner in the last mentioned county.

Of the various earthquakes felt in England within this century, those to which the one here treated of has most analogy

are, that of September 30, 1750;* that of September 14, 1777;† and that of February 25, 1792.‡ The earthquake of last year was of much greater extent than either of the others, consequently a much greater number of counties came within its influence; but there is, to a certain degree, a general analogy in the tract of country affected. It is also observable, that the direction assigned to the abovementioned three former earthquakes, is nearly the same as that I have supposed to have been the direction of the one here described.§ This recurrence of earthquakes, in former tracts, has been long observed in all countries much subject to them; and has, with great reason, been considered as a strong argument in support of the opinion, that their cause is situated within the earth.

It has also been observed in many earthquakes, as in this, that, whatever was the state of the wind some time before, it was calm at the instant the earthquake happened. This has indeed been so generally the case, as to have induced some to suppose that wind would prevent a certain accumulation in the atmosphere, which, according to their theory, is necessary for the production of an earthquake.‖ Unfortunately for that theory, however, there are more instances than one of earthquakes having happened during a gale of wind.¶

* Described in the Philosophical Transactions, Vol. XLVI. page 701, *et seq.*

† Described in the Phil. Trans. Vol. LXVIII. page 221.

‡ Described in the Phil. Trans. for the year 1792, page 283.

§ See Phil. Trans. Vol. XLVI. page 722; Vol. LXVIII. page 227; and that for the year 1792, page 287.

‖ See Phil. Trans. Vol. XLVI. page 676.

¶ Dr. Thomas Heberden, in his account of an earthquake felt in the island of Madeira, March 31, 1761, says, "though it has been remarked that a calm always

Some persons thought this earthquake was most severely felt in high situations; others remarked that some low places were just as much affected: upon the whole, there does not seem room for any material inference on this head.

That the waters about Nottingham should not, according to Dr. STORER's observation, have suffered any remarkable agitation or elevation, may be thought surprising; especially when it is recollected that the earthquake of November 1, 1755, which was so fatal to the city of Lisbon, occasioned an unusual agitation of the waters in various parts of this kingdom, without occasioning any perceptible motion of the earth in those parts.* A similar circumstance, however, is recorded by M. BERTRAND, respecting an earthquake which was very severe in many parts of Switzerland, on December 9, 1755, but which, as he says, produced little or no agitation of the lakes there; whereas a very considerable one had been produced in them by the earthquake of November 1, in the same year, though it was but slightly felt upon the earth.†

" attends an earthquake, no such thing happened now; a fine gale of wind blowing " before and after, as well as during the time of, the shock." (See Phil. Trans. Vol. LII. page 156.) M. BERTRAND also, speaking of an earthquake felt at Zuric, December 9, 1755, says, " Le tremblement étoit accompagné d'un vent violent, que quelques " personnes ont apperçu dès le commencement, d'autres à la fin des ébranlemens." See *Recueil de divers Traités sur l'Histoire Naturelle de la Terre, par* M. E. BERTRAND, page 289.

* See Phil. Trans. Vol. XLIX. page 351, *et seq.*

† Of so remarkable a circumstance, it may not be amiss to give M. BERTRAND's account in his own words: " A Vevey, les rues le long du lac ont été plus agitées; les " cloches ont donné du son; quelques vases ont été renversés; des portes ont été " ouvertes; des tuiles sont tombées des toits, &c.—Ni à Vevey, ni ailleurs, sur les " bords du lac Leman, on n'a apperçu aucune hausse de ses eaux. Il est bien re- " marquable que les lacs de la Suisse aient été plus émus du tremblement de terre du

The wind felt in the mine at Ashover, was probably the effect of the blast mentioned by Mr. GREGORY. Similar blasts have been taken notice of in many other earthquakes; a rushing wind is said to have accompanied that felt in England, September 14, 1777.*

With respect to the other unusual atmospherical circumstances with which this earthquake was accompanied, I shall only observe, that similar ones, particularly black dense clouds, coruscations in the air, &c. have been noticed in several other earthquakes; yet, upon the whole, perhaps few have been attended with more remarkable circumstances of that kind. How far they were connected with the earthquake, it is impossible to determine; be that as it may, it must be allowed that they appeared to be so, to such a degree as very naturally to incline those who noticed them to be of opinion, that the cause of the earthquake was situated in the atmosphere. Upon this head I cannot help remarking, that those who entertain that opinion respecting the cause of earthquakes, seem always to conclude that the electric fluid must, in that case, necessarily be the agent. This, I think, is going too far: we surely do not know enough of the nature of the atmosphere to warrant us in making such a conclusion; and what we do know of electricity (either natural or artificial) rather leads us to conceive that the electric fluid is formidable only when concentrated, or collected within a certain space, and moving with

" premier Novembre, que de celui du neuvième Decembre; quoique le premier ne se " soit fait sentir dans les terres que légèrement, et dans un petit nombre d'endroits; " au lieu que le dernier a secoué tout le terrein, sans emouvoir les eaux. Pourquoi " cette différence dans les effets?" BERTRAND, *Recueil de divers Traités, &c.* page 283.

* See Phil. Trans. Vol. LXVIII. p. 227.

infinite velocity; consequently its effects are limited in their extent, and it is instantaneous in its operation. Whereas earthquakes have, more than once, extended their effects over immense portions of the globe; and they appear to move (sometimes at least) with a degree of slowness of which we cannot suppose the electric fluid capable, without supposing it thereby so far divested of its destructive power, as to be incapable of producing what is truly considered as the most dreadful of all natural phænomena.*

The foregoing reflections are offered as naturally arising from the consideration of the account here given, and by no means as taking either side of the great question, whether earthquakes are to be considered as terrestrial or as aerial phænomena. A question which appears to me to be involved in the greatest obscurity; and this obscurity seems to arise, not so much from a want of arguments on either side, as from the arguments on both sides being so many, and so strong, that the mind hesitates less which side to choose, than which to reject. For as, on the one hand, there are many circumstances attending on earthquakes, (particularly their frequent recurrence, in many parts of the world, in the same tract,) on which it is impossible to reflect, and not feel disposed to believe their cause situated in the earth; so, on the other hand, it seems equally impossible to reflect on the unusual atmo-

* Of the slowness here spoken of, the earthquake described in the foregoing pages affords sufficient example, particularly in its progress from Kenilworth to Wollaton; (see page 374;) but, in the account of an earthquake felt near Oxford, June 19, 1665, it is said, that "Dr. HOLDER, F. R. S. who was then at Blechington, took notice that it "was observed by those in the further part of the garden, some very discernible time "before it was observed by those in the house, creeping forward from the one place to "the other." See Phil. Trans. Vol. I. page 169.

spherical appearances, with which the earthquake here described and many others have been accompanied, and suppose all those appearances merely accidental, and unconnected with the earthquakes. It is not, however, my intention to enter into a minute examination of this part of the subject; but I cannot refrain from hinting, that those who may hereafter be inclined to do so would perhaps do right to begin by inquiring, whether all commotions of the earth which go under the name of earthquakes are really produced by the same cause.* After that, as a subject so full of difficulties ought to be viewed in every possible light, it might not be amiss to consider whether, supposing the cause of an earthquake situated in the earth, that cause may not be capable of affecting the atmosphere, in such a manner as to occasion those appearances in it which we find so difficult to explain; or whether, if the cause be supposed to be seated in the atmosphere, certain tracts of country may not (from some circumstances with which we are unacquainted) possess a peculiar disposition to bring that cause into action, by co-operating with it.

* To prove that this is not an unnecessary inquiry, it might perhaps be sufficient to refer to what has been said respecting the agitation of the waters; (page 376;) but, as a farther proof that earthquakes either differ from each other, or appear to do so to different persons, I may add, that though I have endeavoured to show that the slowness with which earthquakes sometimes move is a strong argument against their being caused by electricity, yet Dr. STUKELEY, the first promulgator of the electric theory, as one of his arguments in its favour, says that, as far as he could learn, the earthquake of September 30, 1750, was felt over its whole extent precisely at the same instant. (See Phil. Trans. Vol. XLVI. page 738.) BECCARIA also, whose theory is an electric one, (though very different from Dr. STUKELEY's, inasmuch as he considers the electric fluid within the earth to be the chief agent,) lays great stress, in support of his theory, upon the velocity with which, as he says, earthquakes move. See *Beccaria, dell' Elettricismo artificiale e naturale*. Cap. vii. § 679.

I have ventured to propose the consideration of these mixed causes,* if I may so term them, because I think it very certain that none of the theories hitherto formed respecting earthquakes, are by any means adequate to explain their various phænomena. I leave it to future theorists, should any adopt the principle, to determine which of the elements is concerned in a primary, and which in a secondary way; also what share in the attendant phænomena is to be assigned to each element.

In whatever light the subject is viewed it seems to present so many difficulties, that perhaps the best we can do is, to consider our knowledge respecting earthquakes as consisting merely in a certain number of facts, to which many more must probably be added, before we shall be able to understand the cause of a phænomenon whose dreadful effects have, in all ages, been too well known in every quarter of the world. So frequent indeed are earthquakes in some parts, that it is impossible, without being fully sensible of our happiness, to reflect

* Dr. HALES's theory of earthquakes was founded upon a sort of mixed cause: he supposed sulphureous vapours to arise from the earth, and to form clouds, the explosive lightning of which kindled the ascending vapours in the earth, and thereby caused what he calls an *earth lightning*; which lightning he considered as the immediate cause of earthquakes. Yet, so imperfect was the aerial chemistry of those days, that the experiment by which he illustrates the operation of his sulphureous vapours, consists only in mixing together nitrous gas and common air, to show the red fumes, and diminution of bulk produced. (See Phil. Trans. Vol. XLVI. page 672 and 677.) If Dr. HALES had been acquainted with modern chemistry, he would undoubtedly, I think, have made inflammable gas the basis of his theory; and indeed, when it is considered that there are great quantities of this gas in the earth, that it readily ascends into the atmosphere, and that, when inflamed, it is capable of producing the most violent effects, it appears to me that it has at least as much claim as the electric fluid, to be reckoned among the probable agents in earthquakes.

on their comparative infrequency here; which is such as to give us every reason to hope, that (whatever philosophy might gain by the extension of our knowledge on so interesting a subject) the island we inhabit will contribute but a small share of those materials which are still wanting to form a complete theory of earthquakes.

XVI. Newton's *Binomial Theorem legally demonstrated by Algebra.* *By the Rev.* William Sewell, *A. M. Communicated by Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read May 12, 1796.

LET m and n be any whole positive numbers; and $\overline{1+x}|^{\frac{m}{n}}$ a binomial to be expanded into a series, as $1+Ax+Bx^2+Cx^3+$, &c. where A, B, C, D, &c. are the coefficients to be determined.

Assume $v^n=\overline{1+x}|^{\frac{m}{n}}=1+Ax+Bx^2+Cx^3+Dx^4+$, &c.

And $z^n=\overline{1+y}|^{\frac{m}{n}}=1+Ay+By^2+Cy^3+Dy^4+$, &c.

Then will $v^n=1+x$, and $z^n=1+y$ $\therefore v^n-z^n=x-y$.

And $v^m-z^m=A\times\overline{x-y}+B\times\overline{x^2-y^2}+C\times\overline{x^3-y^3}+D\times\overline{x^4-y^4}+$, &c.

Consequently $\frac{v^m-z^m}{v^n-z^n}=A+B\times\overline{x+y}+C\times\overline{x^2+xy+y^2}+D\times\overline{x^3+x^2y+xy^2+y^3}+$, &c. Now $v^n-z^n=\overline{v-z}\times:v^{n-1}+v^{n-2}z+v^{n-3}z^2+$, &c.....$z^{n-1}$. Also $v^n-z^n=\overline{v-z}\times:v^{n-1}+v^{n-2}z+v^{n-3}z^2+$, &c....$z^{n-1}$. Therefore $\frac{v^m-z^m}{v^n-z^n}$ reduces to, and becomes $=\frac{v^{m-1}+v^{m-2}z+v^{m-3}z^2+,\ \&c....z^{m-1}}{v^{n-1}+v^{n-2}z+v^{n-3}z^2+,\ \&c....z^{n-1}}$ $=A+B\times\overline{x+y}+C\times\overline{x^2+xy+y^2}+D\times\overline{x^3+x^2y+xy^2+y^3}+$, &c.

The law is manifest; and it is likewise evident that the

numerator and denominator of the fraction, respectively terminate in m and n terms. Suppose then $x = y$; then will $v = x$; and our equation will become $\frac{mv^{m-1}}{nv^{n-1}}$, or $\frac{mv^{m-n}}{n} = A + 2Bx + 3Cx^2 + 4Dx^3 +$, &c.

But $v^n = 1 + x$, therefore by multiplying we have $\frac{mv^m}{n} = A + \overline{A + 2B}x + \overline{2B + 3C}x^2 + \overline{3C + 4D}x^3 +$, &c. Or $v^m = \overline{1 + x}^{\frac{m}{n}} = \frac{nA}{m} + \frac{nA + 2nB}{m}x + \frac{2nB + 3nC}{m}x^2 + \frac{3nC + 4nD}{m}x^3 +$, &c. Compare this with the assumed series, to which it is similar and equal, and it will be

$$\frac{nA}{m} = 1$$

$$\frac{nA + 2nB}{m} = A$$

$$\frac{2nB + 3nC}{m} = B,$$

&c. =, &c.

$$\therefore A = \frac{m}{n};\ B = \frac{\overline{m - n}A}{1.2.n};\ C = \frac{\overline{m - 2n}B}{1.2.3.n};\ \&c.$$

Therefore $\overline{1 + x}^{\frac{m}{n}} = 1 + \frac{m}{n}x + \frac{m \times \overline{m - n}}{1.2.n^2}x^2 + \frac{m \times \overline{m - n} \times \overline{m - 2n}}{1.2.3.n^3}x^3 +$, &c. the law is manifest, and agrees with the common form derived from other principles.

Scb. In the above investigation, it is obvious that unless m be a positive whole number, the numerator abovementioned does not terminate: it still remains, therefore, to shew how to derive the series when m is a negative whole number. In this case, the expression $(v^m - z^m)$ assumes this form, $\frac{1}{v^{-m}} - \frac{1}{z^{-m}}$, or its equal $\frac{z^m - v^m}{v^m z^m}$, which divided by $v^n - z^n$, as before, gives $\frac{1}{v^n z^n} \times \frac{z^m - v^m}{v^n - z^n} = \frac{1}{v^n z^n} \times \frac{-\overline{v - z} \times : v^{m-1} + v^{m-2}z + v^{m-3}z^2}{v - \times : v^{m-1} + v^{m-2}z + v^{m-3}z^2 +}$, &c. =

$\frac{-1}{v^m z^n} \times \frac{v^{m-1}+v^{m-2}z+v^{m-3}z^2+, \&c.}{v^{-1}+v^{-2}z+v^{-3}z^2+, \&c.} = (\text{when } v=z) -\frac{mv^{m-1}}{v^m \times nv^{n-1}} = \frac{-mv^{m-n-1}}{n}$, which is the same as the expression $\left(\frac{mv^{m-n}}{n}\right)$ before derived with only the sign of m changed. The remainder of the process being the same as before, shews that the series is general, or extends to all cases, regard being had to the signs. Q. E. D.

XVII. *A Description of the Anatomy of the Sea Otter, from a Dissection made November 15th, 1795, by* Everard Home, *Esq. F.R.S. and Mr.* Archibald Menzies. *Communicated by* Everard Home, *Esq.*

Read May 26, 1796.

THE subjects from which the following description is taken, were procured from the natives on the west coast of America, near Queen Charlotte's isles, by Mr. ARCHIBALD MENZIES, surgeon in the navy, and naturalist to the expedition fitted out by government for making discoveries, under the direction of Captain VANCOUVER.

The sea otter is not confined to this particular situation; it was met with in the course of the voyage every where along the coast, from 30° to 62° north latitude, and sometimes even an hundred leagues out at sea.

Two sea otters were examined, both of them males; one was a cub not old enough to leave the mother, the other appeared to be full grown.

A Description of the external Appearances.

The large one measured four feet four inches from the nose to the extremity of the tail. The body appears a little compressed, and is nearly of the same thickness throughout; its circumference is two feet four inches and an half.

The colour of this animal varies in different subjects, but in general the head and neck are grey, or of a silver colour; the back, sides, legs, and tail, black and glossy; in some, the longest hairs are tipped with white, which gives them a beautiful greyish cast; the breast and belly also vary from a silver grey, to different shades of light brown. The long hairs shine with a brilliant gloss, but the short fur is exceedingly fine, soft, and thick set; and its colour is either a light chesnut-brown, or it has a silver hue, and a beautiful silky gloss.

In the cub state, the hair is a long, coarse, shaggy fur, of a brown colour, destitute of any gloss; but as the animal grows up the fur becomes finer and more beautiful.

There are two nipples, one on each side of the sheath of the penis, nearer to the anus than to the external orifice of the sheath.

The sheath of the penis does not project beyond the skin of the neighbouring parts; its external orifice is seven inches from the anus, but the sheath itself extends an inch and half further on under the skin of the belly; by which means the penis, when inclosed in it, has its point more effectually defended from injury.

The head is somewhat compressed, and small for the size of the animal. The nose and upper lip are very muscular, and protrude about an inch and half beyond the gums and lower lip. The eyes are small, and placed directly over the angles of the mouth, about half way between the ears and the tip of the nose.

The ears are nearly naked, black, slightly notched at the ends, and about an inch long; they are six inches removed from the tip of the nose.

The whiskers are in great number, they are white and strong, they arise from the upper lip on each side of the nose. There are a few weak long hairs on the eyebrows.

In the upper jaw there are six conical incisor teeth, regularly placed; of these the middle ones are the smallest. Two strong conical fangs, $\frac{1}{4}$ths of an inch long, measuring from the edge of the gums; on each side there are two small obtuse pointed teeth, of which that next the fang is much the smallest; and two broad molares with very irregular grinding surfaces.

In the lower jaw there are four incisores, flatter than those in the upper; two fangs, shorter than the upper ones; and on each side two small teeth and three molares, similar in appearance to those in the upper jaw.

The fore legs are short and strong, with palmated feet; each foot has five toes. They are covered with a thick black fur, which has a fringe of the same colour round the edge of the sole of the foot, where the fur terminates.

The hind legs, when stretched backwards, reach nearly to the end of the tail, and are well adapted for swimming, having five long wide-spreading palmated toes with claws, of which the innermost is the shortest; they measure across eight inches, and are completely covered with fur, except a small spot under the extremity of each toe. The claws are of a light colour, and channelled on the under surface; those on the fore feet are small, and placed so far back that they seem of little use but as a defence for the upper part of the toe; those on the hind feet are stronger, and project beyond the toes.

The tail is flat, and tapers to a sharp point; it is covered with a thicker short fur than any other part of the animal.

A Description of the internal Parts.

The panniculus carnosus, which lies immediately under the skin, is very strong, and extends over the greatest part of the body.

The tongue is four inches long, and rounded at the end, in which there is a slight fissure, giving the tip a bifid appearance. The papillæ on its surface are soft; they are long towards the root, but less so near the tip.

The os hyoides, thyroid, and cricoid cartilages are small for the size of the animal, and weak in their texture. The cricoid cartilage is not a circular ring, but made up of two equal parts, united anteriorly; their lower edge at this union forms an acute angle, the two sides pass a little down upon the trachea as they go round it; and the lower edge laps over the upper annular ring of the trachea.

The thyroid gland is small, and divided into two parts.

The epiglottis is short, and its edges are attached by means of a ligament to the inner side of the thyroid cartilage. The passage of the glottis is small.

The rings of the trachea are circular, and disunited behind, so that their edges meet, and when pressed upon, they lap over each other, being bevelled off for that purpose. Towards the bifurcation of the trachea, the space behind, which is not occupied by the cartilaginous ring, is much increased. This space is occupied by a muscle whose principal fibres are transverse. The trachea is very elastic in a longitudinal direction: seven inches of its length being readily elongated to $10\frac{1}{2}$, and immediately upon being left to itself it contracts to its former state.

The lungs onthe right side have three lobes, two large and

one small azygos lobe; the lower lobe sends a process between the pericardium and diaphragm. On the left side there are two lobes. The lungs were completely empty, so as readily to sink in the spirits in which they had been preserved; the cells are very small, and so elastic that they are difficultly expanded, and readily collapse.

The anterior mediastinum is of considerable breadth, but free from fat, consisting of nothing besides the duplicature of the pleura.

In the fœtus there is a very large thymus gland, convex on its external surface, and concave upon the other.

The heart is inclosed in a thin pericardium, is rather short, free from fat upon its external surface, and rounded at the apex. The ventricles have no communication between them, but the foramen ovale between the auricles remained open; the passage was, however, so oblique, that it must have acted as a valve; it admitted a crow quill. In the fœtus it was less oblique. The structure of the heart, and the valves of the aorta and pulmonary artery, are the same as in other animals. There were no remains of the canalis arteriosus.

The aorta had nothing unusual in its appearance, but the vena cava descendens is very large; when slit open, its breadth is $5\frac{1}{2}$ inches.

The œsophagus is small for the size of the animal.

The stomach is bent upon itself, the pylorus being on a line with the entrance of the œsophagus, and not at a great distance from it. The cardia does not project much into the left hypochondre; and that half of the stomach next the pylorus is much smaller than the other. The coats are thin. The internal surface is free from rugæ; the posterior portion is

smooth, without any appearance of glandular structure; the anterior portion is more vascular and villous. At the pylorus there is an oval part of the internal surface of a dark colour, and rougher or more villous than the rest of the stomach, with a determined edge; the small end of the oval extends about half an inch beyond the pylorus into the duodenum; the larger end goes some way into the stomach, and extends chiefly over the posterior surface, also a little way beyond the great arch anteriorly, covering about half the breadth of this part of the stomach; it is nearly as long again as it is broad. This part is probably glandular; it was only seen in the young subject, which from the smallness of its size was more perfectly preserved, and its internal parts better fitted for anatomical examination. At the pylorus there is the usual thickened valvular appearance.

The stomach was entirely empty, and in a very flaccid state.

The duodenum makes a considerable bend downwards on the right side before it crosses the spine, to become a loose intestine; there is no cœcum or difference of size in the intestines, they are all strung upon the mesentery till within 15 inches of the anus; this part of the gut crosses the spine above the root of the mesentery, and passes down to the anus. The intestines have no valvulæ conniventes; they were 52 feet long, which is 12 times the length of the animal. In a common otter, the intestines are only $3\frac{1}{4}$ times the length of the animal.

In a common otter two bags are found at the anus, but there are none in the sea otter.

The mesentery is 7 inches broad, and its lower part, which may be called meso-rectum, is only five inches in breadth.

The mesentery is thin, and has a great many blood-vessels which are accompanied with fat. There are no lymphatic glands upon the general membrane, but a cluster of very large ones close to the root of the mesentery. The lacteals appear a little larger than in the human subject, but the circumstance of the animal having been two years in spirits, was very unfavourable for their examination.

The omentum is a thin reticular membranous double bag, covering the whole of the intestines; it is attached anteriorly to the great curvature of the stomach, but not to the duodenum; posteriorly to the loins.

The liver is made up of five lobes, besides the lobulus Spigellii; three on the right of the falciform ligament, two on the left.

The gall-bladder is found in the usual situation, is bent in the middle upon itself, and is 6 inches long. The cystic and hepatic ducts unite at the external surface of the duodenum, forming a common canal, or ductus communis cholidochus, about an inch and half long, of an oval shape, with an irregularly rugous internal surface, placed between the muscular coat and the internal membrane of the intestine; it opens into the duodenum by a projecting orifice 2½ inches from the pylorus.

The vena portarum is very large, and the passage behind the ducts of the liver into the cavity of the little epiploon is also large.

The pancreas is situated across the spine behind the stomach, it is not confined within the usual limits, but extends along the posterior membrane of the omentum. It is subdivided into a number of small parts, of an oval shape, all at a certain distance from each other, united by blood-vessels re-

sembling small leaves upon the branch of a shrub. The little pancreas puts on the same appearance, covering the whole meso-duodenum, which is unusually broad. The duct of the pancreas is of the ordinary size, it opens into the duodenum by a separate orifice $1\frac{1}{2}$ inch from the pylorus.

In the common otter the pancreas has not this unusual subdivided appearance, and the duct opens by a common orifice with those of the liver into the duodenum.

The receptaculum chyli is an oval bag, $\frac{4}{4}$ths of an inch broad, from which two trunks go off to form the thoracic duct, each of them about $\frac{1}{3}$th of an inch in diameter; these anastomose frequently in their course, so that there are always two, sometimes three, and even four trunks, running parallel to each other; the thoracic duct is 8 inches in length.

The kidneys are conglomerated, six inches long, and three broad.

The urinary bladder is pendulous and pyramidal, and the ureters open into it very near each other at the lower posterior part.

The testicles are situated under the external skin on each side of the sheath of the penis, but have no pendulous scrotum. They are small, flat, and oval. The tunica vaginalis communicates with the cavity of the abdomen. The cremaster muscle is very strong.

The vasa deferentia, as they pass behind the bladder, become a little convoluted, and open into the urethra at the caput gallinaginis.

The penis, in the relaxed state, is 8 inches long, the bone 6 inches. The corpora cavernosa are small, but strong in their coats. The bone near its anterior end appears to be covered

with a quantity of loose cellular substance; this in the erected state is filled with blood, and forms a large glans six inches in circumference, and four inches long; its anterior extremity is concave, and the end of the bone is seen in the centre.

The penis, when erect, is 11 inches long. The erectores muscles are very strong.

The globe of the eye is extremely small, and the optic nerve is small in the same proportion. Its internal parts were not in a state to bear examination.

The articulation of the lower jaw admits of no motion forwards or laterally; it is a simple hinge an inch long, and very narrow. The condyle of the jaw is so much inclosed in the socket as to be with difficulty disengaged.

The ribs are 14 in number, nine true, and five spurious.

EXPLANATION OF THE PLATES.

Tab. VIII. A side view of the scull of the sea otter, in which the articulation between the scull and lower jaw is different from that in other animals: the condyle of the jaw is almost completely confined in the cavity adapted for it in the basis of the scull, so as to prevent all lateral motion, and make the teeth, when the jaws are closed, always touch upon the same surfaces.

Tab. IX. A view of the basis of the scull, and the lower jaw separated from each other, to show the number and appearance of the teeth; and the peculiar shape of the condyles of the lower jaw, and of the oblong cavities in the basis of the scull with which they are articulated.

Tab. X. fig. 1. A view of the thoracic duct, which in this

tribe of animals is a kind of chain made up of several ducts, and not single, as is more commonly the case in the human body:

a, The receptaculum chyli.

b, The duct which passes over to the left side.

c, A lymphatic vessel from the neck.

The animal's having been preserved two years in spirits prevented the terminations of the ducts in the veins being shown, as they were not filled, the state of the parts not allowing the injection to pass so far.

Tab. X. fig. 2. The penis filled with injection, putting on the same appearance as when erected in the living animal.

aaa, The crura and corpora cavernosa penis.

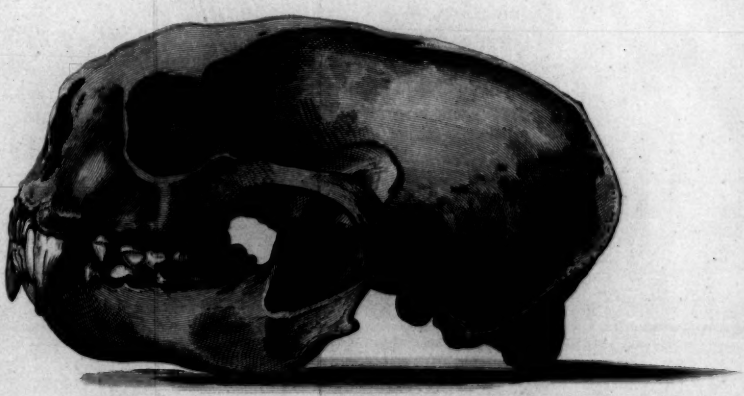
b, The bone of the penis, seen through the membranes which cover it.

c, The end of the bone in the centre of the glans.

d, The glans penis, which at its anterior extremity forms a cavity with a well defined edge; from the centre of this cavity projects the bone and the orifice of the urethra.

e, A large vein going along the back of the penis from the glans. In the relaxed state the glans entirely disappears, the penis at that part being only the thickness of the bone covered with skin. The substance of the glans is made up of a fine reticular membranous structure, which in the relaxed state of the parts is completely emptied of its blood.

These plates are nearly the natural size of the parts they represent.



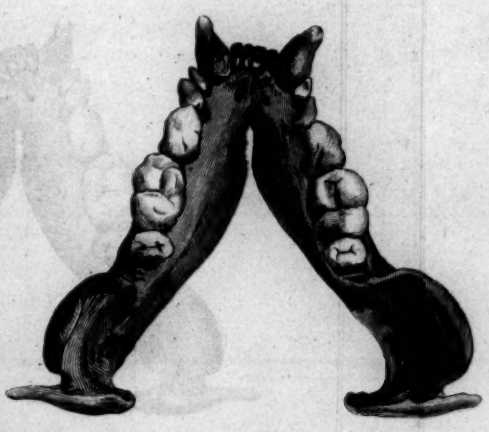
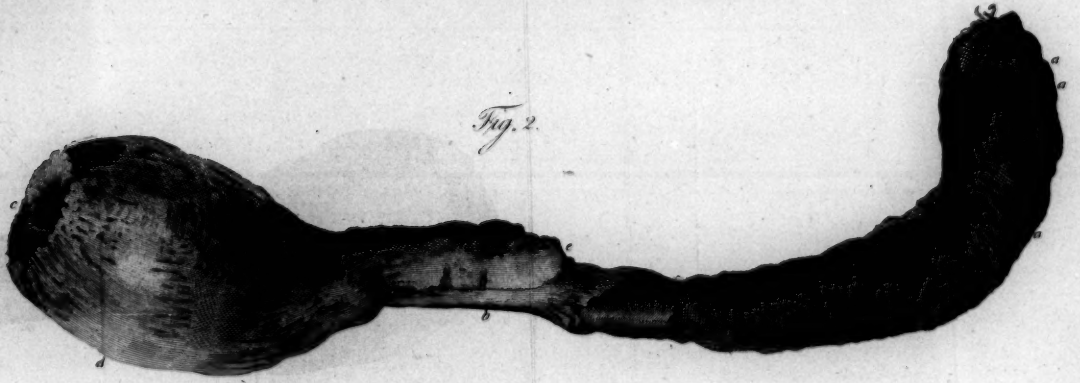


Fig. 1.

Fig. 2.



XVIII. *Observations on some ancient metallic Arms and Utensils; with Experiments to determine their Composition.* By George Pearson, *M. D. F. R. S.*

Read June 9, 1796.

THE opportunity of examining the ancient metal instruments, which are the subject of the present paper, was afforded me by Sir JOSEPH BANKS, Bart. K. B. P. R. S. whose zeal for science induced him to sacrifice them to chemical analysis.

I am further indebted to Sir JOSEPH for almost all the curious particulars relative to the history of these instruments; which he was so kind as to permit me to extract from his own notes.

Most of the articles were found in Lincolnshire, in the bed of the river Witham, between Kirksted and Lincoln. Several of them were discovered when that river was scoured out in 1787 and 1788.

The river Witham, between Lincoln and Tattersall, runs through a country almost level, abounding with moorish soil. Its current is slow, and had for ages been depositing gradually a mud, which possesses powers of preserving things lodged in it for a great length of time. The peat moss also of moorish soils has the same property. Inthe Philosophical Transactions, (Vol. XLIV.) an account is given of a body which was dug up in the isle of Axholme that was judged to be of great antiquity,

from the structure of the sandals on the feet; and yet the skin, with hair upon it, was pliable and soft like doe-skin leather.

The workmen who found several of the articles which are the subject of this paper, and at the same time many other arms and utensils of our Roman, Saxon, and Danish ancestors, universally agreed, that most of them lay at the bottom of the river, on the hard soil, and below all the mud. From which observation it may be inferred, that our Saxon ancestors kept the river in much better condition than their successors have subsequently done; and indeed this conclusion receives a great degree of credit from the arms which, in the year 1788, were brought up by an eel-spear near Kirksted Wath; for in that place, and in some few others, the old bottom lay so low, that those who cleaned the river had not occasion to sink down to it, although they removed as thick a body of mud there as elsewhere.

The instruments of which I shall here give an account, were evidently made of what are commonly called brass, and iron. The brass instruments, as I shall show, were allays of copper by tin; and the supposed iron implements were found to be steel.

It will be proper in this place to observe, that brass is a term commonly used to denote any metallic composition the principal ingredient of which is copper; but the most accurate writers in chemistry use the term brass, with more precision, to denote only the compound of copper and zinc; and therefore I shall employ it in this latter sense.

SECTION I. Of the Copper Instruments.

§ 1. *Miscellaneous historical Observations.*

The articles belonging to this head were seven in number; namely, a Lituus, a Spear-head, a Sauce-pan, a Scabbard, and three Celts.

1. *The lituus:* its figure is shown by the drawing, Tab. XI. fig. 1. It is well known to have been a military musical instrument of the Romans. Several classical writers mention it, as Horace, in ode i.

" Multos castra juvant, et *lituo* tubæ
" Permistus sonitus."————

And Virgil mentions the lituus in celebrating Misenus, who served Hector in the Trojan war, and afterwards Æneas, in the office of trumpeter:

————" Illi Misenum in littore sicco,
" Ut venêre, vident indigna morte peremptum;
" Misenum Æoliden, quo non præstantior alter
" Ære ciere viros, martemque accendere cantu:
" Hectoris hic magni fuerat comes; Hectora circum
" Et *lituo* pugnas insignis obibat et hastâ."

Æn. lib. vi. v. 162.

And again in the Georgics, lib. iii. v. 182.

" Primus equi labor est, animos atque arma videre
" Bellantum, *lituosque* pati, tractuque gementem
" Ferre rotam, et stabulo frænos audire sonantes."

The lituus is supposed by judicious antiquaries to have been adopted from the barbarous nations; and that the figure of it was intended by the barbarians to resemble a snake, the principal object of their religious worship, and of the most sacred

mysteries of the Druidical religion. If these remarks be true, they throw new light on the crooked staff of the augurs, which the lituus much resembles. It is accurately represented among the trophies which ornament the base of TRAJAN's column at Rome, erected in memory of his conquest of the Dacians and Sarmatians, and covered with bas-reliefs, describing the events of that war. The lituus is also found on the reverses of some Roman coins: see fig. 2.

The specimen before us was found in the river Witham, near Tattersall ferry, in 1768. It is imperfect, a little of both ends being broken off; but notwithstanding these defects it is a very valuable relic, as there is little doubt that it is the only one known to be in any cabinet at this time in Europe. It has been neatly made. The parts which appear like joints are pieces which slide over the tube for ornament, or perhaps for holding the instrument more conveniently. It had the appearance of a brazen tube, from which a great part of a blackish coating had been rubbed off. It was evidently made of a plate of hammered metal of about one-twentieth of an inch thick. The juncture of the edges of the metal, the whole length of the tube, was preserved by means of a solder clumsily applied, by melting it withinside the tube. This solder, which was readily melted out by a red hot iron, was ascertained to be merely tin; for it afforded rapidly oxide of tin by applying nitric acid; the cold saturated solution in muriatic acid afforded CASSIUS' precipitate on dropping into it nitro-muriate of gold; and it afforded no acetite of lead on digesting it in acetous acid.

The black coating was easily scraped off with a knife, but the quantity of it was too small to enable me to determine whether it had been applied by art, or was the accidental

effect of the mud or earth in which it had been buried for many ages. The ancients, as PLINY informs us, stained plates of one sort of copper, the *æs coronarium*, with ox gall to make it look like gold: and the crowns and chaplets of public actors were made of copper so coloured.* It, perhaps, will not appear very improbable, that the coating of the lituus was with this substance.

The performers on the lituus among the Romans, seem to have been persons of at least as high rank as the stage players, and with propriety might therefore use instruments as highly ornamented.

II. Tab. XII. represents a *Spear-head*. In Sir JOSEPH BANKS's collection there is a British spear-head of bone, a Norman one of iron, and a third, the article before us, of copper, which is believed with the greatest reason to be Roman workmanship.† This Roman spear-head is worthy of admiration and imitation, on account of its figure, weight, and size, as an offensive weapon. It is however made of cast metal, as appears from its rough surface, figure, texture, and grain. That it is made of bad metal will be made appear hereafter. It has not been hammered, but has been cast hollow to receive a wooden shaft, and in order to be light and save the expence of metal. It is evident from its figure, that it is of the very best conceivable form for piercing, and for inflicting the largest wound at the least expence of weight and bulk. This weapon was found in the river, with another, near Fiskerton, in the year 1788.

* "Coronarium tenuatur in laminas, taurorumque felle tinctum, speciem auri in coronis histrionum præbet." PLINY, lib. xxxiv. cap. viii.

† An instrument is described and represented by a figure in the Archæologia, Vol. IX. fig. *e*, exactly like this spear-head, and it is deemed to be Roman.

III. The *Sauce-pan* is represented in Tab. XIII. From its form and the grain of its fracture, and its being one entire piece, it appears to have been made of cast metal. It is considered to be a piece of Roman workmanship. It is neatly and curiously grooved at the bottom, to admit the fire to penetrate to the contents more easily. On the handle is impressed, seemingly with a stamp, C ARAT; which letters may possibly signify CAIUS ARATUS, as the latter part of the stamp seems not to have made an impression.

It was found in the year 1768 in the river Witham, near Tattersall ferry. It appeared to have been tinned, but almost all the coating had been worn off. As it was said that it had been used by some boatmen, for some time after it had been found, it might have been tinned after it got into their possession. The art of tinning copper, however, was understood and practised by the Romans,* although it is commonly supposed to be a modern invention, therefore it is not very improbable that this utensil was originally covered with tin by that people.

IV. Tab. XI. fig. 3. represents the *Scabbard* with a sword of iron within it. This and another brass scabbard in Sir JOSEPH BANKS's collection were found in the river Witham in 1787, near the site of Bardney abbey. In the same place were found many other arms; from whence some conjecture respecting their antiquity may be formed. We may suppose that the destruction of that noble monastery was not effected without loss on the side of the Danes who attacked, and the Saxons who defended it. By the best accounts it was destroyed in the year 870.†

* "Stannum illitum æneis vasis, saporem gratiorem facit, et compescit æruginis "virus." PLINY, lib. xxxiv. cap. xvii.

† TANNER's *Notitia Monastica*, p. 248.

These swords are therefore prior to the conquest; but which are Danish and which are Saxon, is not easy to determine. Probably these people, who were always at war with each other, and consequently had frequent opportunities of possessing themselves of each other's weapons, adopted from each other whatever improvements were made by either; and thus in effect they might both use the same weapons. Swords like this are to be seen in illuminated manuscripts, and on painted glass. In STRUTT's Dorea Anzel-cynnan, where he describes the customs of our Saxon and Danish ancestors, such swords frequently occur; especially in the lives of the two OFFAS. Similar swords are also in the hands of the Danes, who are killing the abbot of Croyland on the shrine, as delineated by Dr. STUKELEY, in the Philosophical Transactions, Vol. XLV. p. 597.

The brass scabbard before us possesses some degree of elegance, and much accuracy of workmanship. It appears to have been originally covered with a bright blue varnish, but the quantity was much too small for ascertaining its nature. Exactly such a sword as this is represented at the side of a Danish soldier, in pl. 26, Vol. I. of STRUTT's work just quoted. The sword within this scabbard was destroyed by rusting, and could not be drawn out. The pommel and guard had been broken off. There was a plate of open work, about four inches long, laid over one side, and near the top of the scabbard; and at the bottom, on one side, was a sort of joint; and on the other and opposite side was a bas-relief figure. The scabbard was made of hammered metal, and was perhaps about one-thirtieth of an inch thick.

The next, and last three articles under the present head, are

known to antiquaries by the name of *Celts*. They were, probably, instruments used by the ancient Britons, Gauls, or Celtæ. The learned do not agree whether the celts were Roman workmanship or not: nor to what particular uses they were applied. Accordingly some persons have supposed that they were the offensive weapons of our ancestors; and others have supposed that they were both offensive military weapons, and civil instruments; but the most probable opinion is, that they were merely domestic tools. Many of the celts are cast after the model of stone implements, which are confessedly ancient British or Celtic chopping instruments, and tools for making holes. Several of these stone implements, in Sir JOSEPH BANKS's collection, correspond exactly with the figure and size of the celts. Great quantities of these instruments have been at different times discovered in England, as well as in Ireland, and some few in France. Sometimes they have been found in heaps, as if the owner had, and probably did throw them away by basketfulls, as things of little value. It has been very ingeniously conjectured, that when the Romans came to Britain they found the inhabitants, especially to the northward, very nearly in the same state as that in which our late discoverers found the natives of the South Sea islands. The Britons parted with their valuable articles of food, rarities, and commerce, for metal tools made in imitation of their stone ones; but in time, finding themselves cheated by the Romans, who made these tools of bad metal, of the shape of the ancient British stone axe, as the inhabitants of Otaheite were by the use of base metals; they relinquished these tools when they became acquainted with those made of better metal, and according to the Roman patterns. Hence we see a reason for such great

quantities of celts being found among the Celtic nations, and not among the Roman, excepting now and then a specimen, which may be looked upon as the tool, or spoil of barbarian auxiliaries.

v. Tab. XIV. fig. 1. represents a *Celt*, No. 1. found on the peninsula of Ballrichen, within the precincts of a Druidical grove, or dwelling, in Ireland. The same kind of celt is described in WRIGHT's Louthiana, b. 14. p. 7. pl. i. and also in the Archæologia, Vol. V. p. 113. by Dr. LORT. It weighed one pound and one quarter. Except at the edge it was nearly three-eighths of an inch in thickness. It was of a blackish colour, from oxide of the metal and dirt upon its surface.

vi. Fig. 2. represents the *Celt*, No. 2. It was found in a field, by ploughing, in Cumberland. The celt in Dr. LORT's collection which most resembles this article is delineated by fig. 11. pl. viii. p. 113. Vol. V. of the Archæologia. The celt before us differs from that just referred to, in being grooved on both sides to receive a shaft or handle, instead of having a socket. It weighed nearly three quarters of a pound, and was about five-eighths of an inch thick, except at the edge. Its external appearance was like that of the former celt.

vii. Fig. 3. represents the *Celt*, No. 3. It was much smaller than the two former, weighing only about five ounces, but it resembled in shape fig. 1.

§ 2. *External, or more obvious Properties.*

(*a*) These metallic instruments differed considerably from one another in their external appearance, with respect to colour. A little green or blackish oxide of copper adhered to their surfaces. The lituus, and the celts, No. 1. and No. 2. in

the parts not covered with oxide or dirt, were yellow, like rather pale brass; the scabbard was somewhat less yellow; and the spear-head and sauce-pan were of a pale yellowish-brown colour. The celt, No. 8. was covered entirely with black oxide and other extraneous matter.

(*b*) A small part of the surface of each of the articles being filed or rubbed to remove the exterior matter, the colours of all of them were what I would call different shades of pale copper colour; not very different from gun metal and prince's metal, but not at all like brass. They all took a fine polish, which, when first produced, was pale coloured and whitish; but, by exposure to the air, it became deeper coloured and tarnished. On examination of the polished surfaces with a lens, the metallic matter appeared perfectly homogeneous, and of a close texture.

The articles being cut through with a chizzel, the same differences among the cut surfaces appeared, as among the polished surfaces just described. On fracturing the metallic bodies, the visible interior structure or texture did not appear similar in colour and grain.

The *spear-head* was open grained, almost as copper; and porous, as if made of bad metal, but of a blackish-brown, or dark grey colour.

The *sauce-pan* was also open grained or porous, although less so than the spear-head. The colour of the grain, like that of the spear, was dark brown or grey.

The *lituus* and the *scabbard* were close grained; lighter coloured than the former, but grey.

The *celts* were all open grained, but much less so than the pan and spear-head; and differed from them in being brown.

The celts when lacerated exhibited shining facets, and striæ or radii. The cut surface, and also the grain of the celt, No. 3. was much paler than the cut surface and grain of the other two celts.

An experienced observer can judge tolerably well concerning many metals, and metallic compositions, by inspecting fractured surfaces; but to judge accurately from these appearances, the metals to be compared with one another should be in the same state of aggregation.

I therefore melted the old implements, and cast them into the same ingot mould. In this state I could also judge better of their hardness, brittleness, strength, malleability, and other properties, but especially of their specific gravity.

Each of these ingots was fractured by a pretty smart stroke with a hammer. The fractures of all the metals were, in this state, close, or fine grained; and therefore denoted hardness. Their appearances were the following.

1. The *celt*, No. 1. Less close grained than the rest, and pale brown.

2. The *celt*, No. 2. Fine grained, and greyish brown.

3. The *celt*, No. 3. Still finer grained; bright greyish, and somewhat crystallized.

4. The *scabbard*. So like the celt, No. 2. that it was not easy to perceive a difference between them in grain and colour.

5. The *spear-head*. Close grained as any of the ingots; but of a dull pale slate colour.

6. The *sauce-pan*. Fine grained, but not so much so as the *lituus*; and of a somewhat slate-coloured hue, or dark grey; but less dull than the scabbard.

7. The *lituus*. Very close grained; of a bright slate and silvery hue, and partly crystallized.

(*c*) The trial with the drill, and with the hammer, showed the lituus to be the hardest of these old metals; almost as hard as bell metal: the next in hardness was the celt, No. 3: the next in order was the pan: and next the celts, No. 1, and No. 2, and the spear-head, which were nearly alike in this property.

They were all much harder than copper, or even than brass.

(*d*) The ingots of the lituus, sauce-pan, spear-head, scabbard, and the celt, No. 3, all broke readily enough with a smart stroke with the hammer, and more readily than the ingots of the celts No. 1. and No. 2. Plates of the spear-head and pan possessed little malleability and ductility; being very liable to be cracked in beating them, as if they had been made of impure metal. The lituus was very flexible, malleable, and elastic; so were plates of the celts, No. 1, and No. 2, and of the scabbard; but the celt, No. 3, although, apparently, made of the purest metal, possessed little malleability. They were all less malleable than brass. The celts, No. 1, and No. 2, possessed more strength and hardness conjointly than any metal in use, except iron and steel; and of course are the fittest metal for chopping instruments of any known metal, except iron and steel.

(*e*) The metallic implements before us were all rendered harder, and specifically heavier, by hammering: and they were again rendered softer, and specifically lighter, by annealing, that is, by ignition and gradually cooling.

(*f*) These ancient metals were very sonorous, particularly the sauce-pan, the lituus, and the celt No. 3.

§ 3. *Specific Gravities.*

These were ascertained by weighing the metallic instruments themselves, as well as after melting and casting each of them in the same ingot mould.

1. The lituus, before melting — —	8,3
Ditto, after melting — —	8,85
Ditto, another piece, after melting	8,888
Ditto, another piece, after melting	8,650
2. The spear-head, before melting —	7,795
Ditto, after melting —	8,805
Ditto, another piece of ditto —	8,850
Ditto, another piece of ditto —	8,830
Ditto, another piece of ditto —	8,860
3. The sauce-pan, before melting —	7,960
Ditto, another piece — —	8,255
Ditto, after melting — —	8,630
Ditto, another piece of ditto —	8,769
Ditto, another piece of ditto —	8,740
4. The scabbard, before melting —	8,5
Ditto, another piece — —	8,6
Ditto, after melting — —	8,657
Ditto, another piece of ditto —	8,875
5. The celt, No. 1. before melting —	8,780
Ditto, another piece — —	8,885
Ditto, after melting — —	8,734
Ditto, another piece of ditto —	8,771
6. The celt, No. 2. before melting —	8,680
Ditto, another piece — —	8,653
Ditto, after melting — —	8,474
Ditto, another piece of ditto —	8,600

7. The celt, No. 3. after melting	—		8,854
Ditto, another piece	—	—	8,600

§ 4. *Experiments with Fire.*

(*a*) These old instruments melted at a lower temperature than that at which copper, or even some kinds of brass melt.

Although I did not succeed in determining precisely the temperature at which each of them fuses; it may be useful to relate the experiment made with that view.

(*b*) 100 grains of each of the above seven ancient metallic instruments, and the same quantity of copper, of pure silver, of allay of copper with one-eighth of its weight of tin, of allay of copper with one-tenth of its weight of tin, of allay of copper with one-twentieth of its weight of tin, of allay of three parts of copper with one of zinc, and of gun-metal, were exposed each in separate coppels, under a muffle, to the greatest degree of fire which I could produce in the best assay furnace.

A pyrometer clay piece of WEDGWOOD's instrument was also put into each coppel.

During forty minutes exposure to fire, not one of the metals melted, except the pure silver,* and the allay with zinc: nor did any of them emit visible vapour, or inflame, except the allay with zinc; nor did any matter ooze out of any of the metals.

* In WEDGWOOD's scale it is stated, that pure silver melts at 28°, and Swedish copper at 27°. But every part of the furnace in the above experiments might not be of the same temperature for the same space of time: and perhaps the state of cohesion and figure of the metal exposed to fire may account for the difference in the degree noted by the pyrometer in my experiment, from that stated in the scale. For I am assured, by Mr. THOMAS WEDGWOOD, that the degree of contraction is uniform among a number of pyrometer pieces, exposed in the same part of the furnace at the same time.

On cooling, it was found that the figure of the metals which had not been melted in the coppels was not altered, but they were changed, either totally or externally, into scoria-like black matter. The copper allayed with zinc was found to contain a nucleus of copper within a large proportion of black scoria and white oxide of zinc. The celt metals were changed into scoriæ, including copper-like metal. The other old metals were changed entirely into scoriæ. The copper allayed with one-twentieth of its weight of tin was changed into scoria containing a little copper; but the copper allayed with one-eighth of tin was changed into scoria containing a little copper, seemingly allayed with a much smaller proportion of tin than before.

The pyrometer pieces indicated degrees of fire, which varied between 18° and 21°. The pyrometer piece in the coppel which contained the silver, and also that in the coppel which contained the copper, denoted 20° of WEDGWOOD's scale, or about 9800° of FAHRENHEIT's scale.

(*c*) A thin plate of each of the old metals being exposed to the flame of a candle with the blow-pipe, a blue and green flame appeared, which soon disappeared, although the fire of the candle was applied so as to keep the metal red hot.

The same kind of blue and green flame was emitted from plates of these metals when they were exposed to fire in open crucibles, before they were melted; but it disappeared in a few seconds of time, although the fire was continued to be applied to keep the metal red hot; nor was any such flame produced when the metal was melted in open vessels, or kept stirring when in a fluid state.

(*d*) Each of the ancient metals being melted in close vessels, was then exposed to the air, and stirred with an iron rod;

but none of them emitted any blue flame, or white vapour, as was the case when brass was so treated.

The following experiment, to determine whether the ancient metal instruments contained any gold or silver, was made, while I was present, by Mr. BINGLEY, Assay Master.

(*e*) 50 grains of each of these metals, and as much gun metal, and also the same quantity of brass, were put into separate coppels, together with 150 grains of lead, under the muffle of an assay furnace: 150 grains of lead were also put alone, by way of test, into a separate coppel.

The fire being kept up in the usual way, the brass emitted a blue flame, and began to melt, discharging at the same time white fumes; but soon after it was melted the flame, and white fumes, disappeared. The ancient metals, and also the gun metal, afterwards melted, and without sending forth any flame, but a slight fume was seen when they were in fusion; which was particularly evident from the coppel containing the spear-head metal. This fume was not seen to arise from the coppel which contained lead only; but the Assayers observe it from charges of lead with silver, or lead with gold and silver, when much air is admitted.

The process being finished, nothing was left in the coppels which contained lead only, and lead and brass, except a just visible particle of silver; but in the other coppels there remained about one-third of the original quantity of the ancient metals, and of the gun metal: and therefore into each of these coppels 150 grains of lead were again introduced. The process being performed a second time, every particle of metal was absorbed, excepting a just visible particle of silver in the coppels which contained the celt, No. 2, the metal of the scabbard, and

the gun metal: but there was a much larger globule of silver in the coppel which contained the spear-head metal.

As the only metal which appeared to contain more silver than the test itself was the spear-head, and as it emitted more fume than the rest, I repeated the process on this metal.

The process of cupellation the second time, as before, caused the appearance of the white fume, and afforded a residue of silver, as before, in greater quantity than that of the test. The silver was determined in the most accurate way to amount to the proportion of fifteen grains in a Troy pound of the spear-head metal. There was no gold in this silver, for it dissolved totally in nitric acid.

§ 5. *Experiments with nitric Acid.*

(*a*) A polished piece of each of the ancient metals was just wetted with *nitric* acid. Fumes of *nitrous* acid arose, and the part wetted became *white* and corroded; as is the case when the nitric acid has been applied in this manner to the allay of copper by tin.

(*b*) On 300 grains of each of the above metals, in a small retort, were poured 1800 grain measures of nitric acid, purified by distillation from nitrate of silver, and of the specific gravity of 1,350. The hydro-pneumatic apparatus being affixed, generally from thirty to forty ounce-measures of nitrous gaz came over in the cold, in the course of two to three days. In this time the whole, or at least the greatest part of the metal, was oxidified and dissolved; there being a clear blue solution, with a copious white sediment, and sometimes a part of the undissolved metal.

By means of the fire of a lamp, more gaz came over, which

had been absorbed by the solution, and which also was afforded by the dissolution of the remaining metal.

The whole quantity of nitrous gaz varied, with the same as well as with different metals, between 60 and 85 ounce-measures; but either from my own inability to observe, or from the circumstances on which this variety depended being unknown, I cannot explain the reason of such differences in the result.

(*c*) After the solution (*b*) had stood several days, the clear blue liquor was decanted, and filtrated, from the white sediment: and pure water was poured upon the filter repeatedly, till what passed through was colourless, and almost tasteless. The filtrated liquid was boiled to evaporate all but about six ounces; and it deposited, on standing, a small quantity of white sediment.

The white sediment, from the solution (*b*), being dried, amounted to the following different quantities, from 300 grains of each of the different metals, namely,

1. The sauce-pan, exclusive of a little dirty extraneous matter, – – – 65 grains, or 21½ *per cent.*
2. The spear-head, exclusive of a little dirty extraneous matter, – – – 63 grains, or 21 *per cent.*
3. The celt, No. 3. – 55 grains, or 18½ *per cent.*
4. The lituus, – – 54 grains, or 18 *per cent.*
5. The scabbard, – 48 grains, or 16 *per cent.*
6. The celt, No. 1. – 42 grains, or 14 *per cent.*
7. The celt, No. 2. – 42 grains, or 14 *per cent.*

(*d*) The decanted and filtrated liquid (*c*) being duly evaporated to crystallization, was found to contain nothing but nitrate of copper, and sometimes a very minute portion of

white sediment; for it threw down nothing but prussiate of copper, on adding prussiate of soda; nor was any silver deposited on immersing in it bright copper wire; nor was any precipitation occasioned by adding muriatic acid, or muriate of soda, to the concentrated blue solution.

(*e*). The white sediment (*c*) was a light impalpably fine powder: it had a little metallic taste: it could not be melted with borax by flame with the blow-pipe, but was diffused through that salt, and rendered it opaque.

This sediment dissolved totally, except a little mere dirt, by long digestion in muriatic acid, and immediately in this menstruum when caloric was applied to make it boil.

This solution in muriatic acid did not throw down Cassius' precipitate on adding to it nitro-muriate of gold, but afforded a white deposit exactly like that which is made on adding nitro-muriate of gold to muriate of tin, made either by boiling tin in a large proportion of muriatic acid, or by dissolving oxide of tin (made with nitric acid) in muriatic acid.

The muriatic solution of the white sediment (*c*), on adding prussiate of soda, afforded a precipitate exactly like that which appears on adding prussiate of soda to muriate of tin.

The white sediment (*c*) being mixed with tartar, upon charcoal, the flame of a candle by the blow-pipe was directed upon it; by which treatment small silver-like globules were made to appear. These globules being collected, were digested in the cold, in so small a proportion of muriatic acid as could not dissolve the whole of the globules supposing them to be tin. They were gradually almost all dissolved, and nitro-muriate of gold being added, Cassius' precipitate was immediately deposited. But the metallic globules being dissolved by boiling in a large proportion of muriatic acid, no Cassius'

precipitate was produced on adding nitro-muriate of gold; nor on adding it to tin dissolved by boiling in a large quantity of muriatic acid.

The preceding analytical observations and experiments will, on examination, perhaps be found to contain sufficient evidence to demonstrate that each of the ancient metallic instruments contains copper and tin; and they will also perhaps be found to prove, that these metals contain no other kind of metal, or other species of matter. But, in order to ascertain the proportion of the tin to the copper more accurately than I was able to do by analysis, and also in order to confirm or invalidate the evidence of analysis, I made the following synthetical observations and experiments.

§ 6. *Synthetical Observations and Experiments.*

Experiment 1. 50 grains of tin were united by fusion with 1000 grains of copper. The ingot of this allay of twenty parts of copper by one of tin, when polished, differed from the celt metals in shade of the same colour; these being much paler than this allay. It was a good deal harder, and not so tough as copper, but it was not so hard, and was more tough than the celt metals. Its fracture shewed also a more open grain than the old metals, and more inclining to the peculiar red colour of copper, instead of the brown and grey, or slate colour of the ancient metals.

With nitric acid it afforded, like the ancient metals, a blue liquor, and white deposit of oxide of tin; but in much smaller proportion than any of them; not being more than seven *per cent.*

Experiment 2. 100 grains of tin were united by fusion with 1500 grains of copper. This allay of fifteen parts of

copper with one of tin resembled the celt metals, No. 1 and No. 2, in colour, polished surface, grain of the fracture, and brown colour of the fracture: consequently the red colour of the copper was completely destroyed. It was not, however, so hard, and was stronger than these celt metals; but was harder than the spear and the sauce-pan.

The solution of this allay with nitric acid only differed from that in the former experiment in affording a more copious white deposit, namely, ten *per cent.* of it in its dried state.

Experiment 3. 100 grains of tin were melted with 1200 grains of copper. This allay of twelve parts of copper by one of tin could scarcely be distinguished from the last described allay in the colour of the polished surface, nor was it so much closer grained or lighter coloured in its fracture as might have been expected; nor could I by the hammer distinguish it from that allay in point of hardness and strength. On the trial with the drill, it however betrayed a good deal more hardness. It was almost as hard as the celts, No. 1 and No. 2.

With nitric acid it afforded a deposit of eleven *per cent.* of oxide of tin.

Experiment 4. 100 grains of tin were united by fusion with 1000 grains of copper. This allay of copper with one-tenth of its weight of tin was as pale coloured as the celts, No. 1 and No. 2, but not nearly so pale as the celt, No. 3. I could not distinguish this allay in the properties of hardness and strength from the two celts, No. 1 and No. 2, and the scabbard; but it was harder than the spear-head and sauce-pan, and not so brittle. Its fracture showed the same kind of rather open grain, and texture, as that of the celts, No. 1 and No. 2, be-

fore they were melted, but it was not so close grained as any of the ancient metals after fusion; and it differed from all of them in being of a lightish brown colour.

The solution in nitric acid differed only from the former in affording a greater proportion of white deposit, namely, thirteen grains and a half *per cent.*

Experiment 5. 900 grains of copper were melted with 100 grains of tin: which allay of nine parts of copper with one of tin differed very little from the former.

By means of nitric acid this allay gave seventeen grains *per cent.* of oxide of tin.

Experiment 6. 100 grains of tin were melted with 800 grains of copper. This allay of eight parts of copper with one of tin was also scarcely distinguishable from the two former allays, in colour, strength, appearance of fracture, texture, and polish.

With nitric acid this allay afforded eighteen grains and a half *per cent.* of oxide of tin.

Experiment 7. 100 grains of tin were melted with 700 grains of copper. This allay of seven parts of copper with one part of tin was evidently different from any of the former allays; being harder, more brittle, paler coloured, the fracture showing a much finer grain, and of a grey or somewhat slate-colour. The grain, therefore, of this allay resembles in colour that of the celt, No. 3, the lituus, the spear-head, and the scabbard. It was especially like the lituus and the celt, No. 3, in the rather bright and silvery appearance of the fracture, instead of the dull slate colour of the spear-head and sauce-pan. On trial with the hammer, and the drill, it resembled exactly the lituus in brittleness and hardness. It was a little harder and

more brittle than the celt, No. 3, and of course much more so than the other ancient metals.

This allay, on solution in nitric acid, yielded twenty *per cent.* of oxide of tin.

Experiment 8. 100 grains of tin were melted with 600 grains of copper. This allay of six parts of copper with one of tin was harder than any of the above allays: and perhaps it was harder and more brittle than any of the ancient metals. Its fracture exhibited a still finer, brighter, silvery, and more crystallized grain than any of the preceding allays.

Nitric acid separated from this allay twenty-two *per cent.* of oxide of tin.

Experiment 9. 100 grains of tin were melted with 400 grains of copper. This allay of four parts of copper with one of tin was about as hard and brittle as some sorts of bell-metal. Its fracture was still paler, finer grained, and silvery, than any of the preceding allays.

Nitric acid separated from this allay twenty-seven *per cent.* of oxide of tin.

Experiment 10. 100 grains of tin were melted with 300 grains of copper. This allay of three parts of copper with one of tin, was much harder than any of the preceding ones. It was also much more brittle, the fractured surface was quite smooth, and without almost any grain at all. It was of a silvery hue, and resembled much an ingot of a melted bell; excepting that it was finer grained, and of a duller colour.

Experiment 11. 100 grains of tin were melted with 200 grains of copper. This allay of two parts of copper with one of tin, was as brittle almost as glass. The fracture showed no

grain at all, being quite smooth. Its colour was more like that of silver than any other metal.

Experiment 12. The metal of which what are called *brass guns* are made, does not in general contain a grain of zinc. They are made of an allay of about ten to twelve or thirteen parts of copper, with one part of tin. I found that the shavings of one of these guns melted much more readily than copper. The ingot was not so hard, but tougher than any of the above ancient metals. It possessed nearly the same hardness and strength as the allay, in *Experiment* 3. of twelve parts of copper by one of tin. The colour of the polished surface, and the grain and colour of the fractured surface, resembled pretty exactly that allay. Of course this gun metal is only a little less hard and brittle than the celts, No. 1 and No. 2, but it resembles them very exactly in the colour and texture of the grain.

This gun metal afforded nearly thirteen *per cent.* of oxide of tin, by means of nitric acid.

Experiment 13. 20 grains of tin and 10 grains of zinc were melted with 800 grains of copper. This allay of eighty parts of copper with two parts of tin, and one part of zinc, was a metal which had a very different aspect when polished, as well as when fractured, from either copper, or any of the above allays, or any of the ancient metals. For it had a rich yellowish or golden hue, and was nearly as tough, but a little harder than copper.

Experiment 14. 20 grains of zinc were united by fusion with 800 grains of copper. This allay of forty parts of copper with one part of zinc, was of a yellowish golden hue, and of

course was very different in its external appearance from the allays of copper by tin. Like the allay of *Experiments* 1st and 13th, it was too soft, and, as the artists term it, *clingy*, to receive the impression of lines, figures, and letters, or for instruments in which holes are to be drilled.

The solution of this allay in nitric acid was blue, like those of the preceding allays and old metals, but there was no white deposit.

Observation. This is the proper place for me to observe, that all the above allays, and the gun metal, melted at a lower temperature than copper does; and, as far as I could determine, the temperature of fusion decreases as the proportion of tin increases.

The next experiments were made not only to satisfy myself, that if *iron* had been an ingredient in the ancient metals, it must have been made appear by the test employed; but also to determine the question made by some chemists, whether copper can be allayed by iron; and to show, as others have asserted, the allays of copper by iron, which were employed by the ancients.

From the writings of many able chemists I was inclined to suppose, that a malleable uniform metal could not be composed of copper and iron, without the aid of an intermede. I therefore, in the first place, used tin as the intermede.

Perhaps some of these experiments next to be related may not be found immediately relative, but as they occurred in the course of investigation, and as I believe few experiments of the same kind have been published, perhaps they will be found useful.

Experiment 15. 2000 grains of tin were melted with 1000

grains of steel,* by keeping the two metals in a close crucible exposed to a pretty fierce fire of a melting furnace. An allay was produced of an uniform metallic mass, of the colour of pewter, of a very open grain, but uniform texture; which was as brittle, and not harder than certain kinds of old bad pewter.

Experiment 16. 1800 grains of tin were melted with 600 grains of steel. This allay of three parts of tin with one of steel was perfectly similar to the last allay of two parts of tin with one of steel, excepting that the allay of this experiment was not so hard, and was less brittle.

Having thus prepared the steel for union with copper, by the medium of tin, I added to it copper.

Experiment 17. 600 grains of the allay of *Experiment* 15. were melted with 2400 grains of copper. This allay of twelve parts of copper with two parts of tin, and one part of steel, resembled exactly the allay of six parts of copper with one of tin, in *Experiment* 8. in the colour and grain of the fracture; in its polish; hardness; and brittleness. Its fracture was of course of a slate-coloured hue, or dark grey, somewhat crystallized and silvery. The fracture being inspected with a lens, the grain appeared finer or shorter than that of the allay of six parts of copper with one of tin.

The solution of this metal in nitric acid produced nitrous gaz, a blue solution, and a white deposit; as occurred in the dissolution of the ancient metals, § 5. p. 411, and of the allays of copper with tin, p. 414—419; but the result of the examination of this blue solution and white deposit was different from

* The steel employed was part of a file. Steel was preferred to iron, because it is fusible, but iron is not.

that of the ancient metals, and satisfied my mind completely, that if those metals had contained iron it must have been detected.

(*a*) The blue solution of this experiment being boiled, to carry off redundant acid, and evaporate about three-fourths of its water, prussiate of soda was added. A reddish-brown precipitation ensued, which resembled exactly that produced by adding this test to nitrate of copper.

(*b*) The white deposit of this experiment having been well edulcorated by pure water, was wholly dissolved in muriatic acid. This solution differed from that of all the white deposits of the preceding experiments, in being of a reddish-brown colour, like dilute solution of muriate of iron, and especially in affording a copious precipitation of prussiate of iron by prussiate of soda. With nitro-muriate of gold, however, this solution only produced a slight grey precipitation, as in the former experiments.

Experiment 18. 1000 grains of the allay of *Experiment* 15. were melted with 2000 grains of copper. This allay of about seven parts of copper with two parts of tin, and one part of steel, was an extremely hard metal, much harder than that of the last experiment; and it was very strong, but scarcely malleable. It took a beautiful polish, of a silvery colour. It was of a perfectly homogeneous texture. The grain of its fracture was extremely fine and uniform, and of a grey colour.

Experiment 19. 2000 grains of copper were melted with 200 grains of steel, in a close vessel, by keeping them exposed to a fierce fire in a wind furnace for about twenty minutes. This allay of ten parts of copper with one part of steel, was of a copper colour. The grain of its fracture was coarse, like that of copper. It was harder than copper, and less tough,

but quite malleable. It was about as hard as the allay of twenty parts of copper by one of tin, and consequently was not nearly so hard as the softest of the ancient metals.

Experiment 20. 1000 grains of copper with 500 grains of a small round steel file were exposed to fire, as stated in the last experiment. On opening the crucible, part of the steel only was found to have been melted and united to the copper; but the other part of the steel which retained its form, was thoroughly impregnated or penetrated by copper; so that on breaking the part which had not been melted, and which was very brittle and porous, it was in appearance imperfectly metallized copper. The part of the allay which had been melted was not, as far as I could perceive, different from the allay of the last experiment, except that it was a little harder; being thought to be about as hard as brass.

I have not hitherto set down the specific gravities of the above allays, because I thought it most useful to make the statement of them together in one column, with, at the same time, the specific gravities of different parcels of copper, tin, zinc, brass, and bell-metal.

Specific Gravities.

1.	Plate of copper, a little hammered	8,8
	Another specimen, a little hammered	8,904
	Copper ingot	8,418
	Another specimen of ditto	8,414
	Shotted copper*	8,08
2.	Tin	7,3

* By shotted copper is meant copper which has been poured when melted into cold water, by which it is divided into small globular pieces and grains.

Another specimen of tin - - - - 7,25

3. Zinc - - - - - - - 7,171

Ditto, another specimen - - - - 7,150

4. Allay of copper with $\frac{1}{20}$ its weight of tin; three different parts of the same ingot - - - 8,764

8,760

8,611

5. Allay of copper with $\frac{1}{15}$ its weight of tin, in the state of ingot - - - - - - 8,760

6. Allay of copper with $\frac{1}{12}$ its weight of tin - - 8,700

Ditto, another piece of the same ingot - - 8,677

7. Allay of copper with $\frac{1}{10}$ its weight of tin; two specimens of the same ingot - - - - 8,658

8,671

8. Allay of copper with $\frac{1}{9}$ its weight of tin; two specimens of the same ingot - - - 8,510

8,6

9. Allay of copper with $\frac{1}{8}$ its weight of tin; two specimens of the same ingot - - - - 8,790

8,711

10. Allay of copper with $\frac{1}{7}$ its weight of tin; two specimens of the same ingot - - - 8,766

8,530

11. Allay of copper with $\frac{1}{6}$ its weight of tin, in one large piece, as it cooled in the crucible - - 8,635

12. Allay of copper with $\frac{1}{4}$ of its weight of tin; two different parts of the same ingot - - - 8,966

8,928

13. Allay of copper with $\frac{1}{3}$ of its weight of tin; two different parts of the same ingot - - - 8,944

8,909

14. Copper allayed with $\frac{1}{4}$ of its weight of zinc - 8,400
15. Common brass ingot - - - - 8,300
16. Common brass, hammered - - - 8,500
17. Piece of an old small bell, probably compounded of copper with $\frac{1}{4}$ its weight tin - - 9,
18. Two different parts of the ingot of gun metal of *Exp.* 12. p. 418 - - - 8,5
19. Allay of 80 parts of copper with two of tin, and one of zinc - - - - 8,560
20. Allay of 40 parts of copper with one of zinc - 8,450
21. Allay of 2 parts copper with one of steel - 7,370
22. Allay of 3 parts of tin with one of steel - 7,214
23. Allay of 12 parts of copper with two tin, and one of steel; different parts of the same ingot - 8,534
8,666
8,633
8,720
24. Allay of 7 parts of copper with two of tin, and one of steel - - - - - 8,633
25. Allay of 10 parts of copper with one of steel; two different parts - - - - 8,625
8,600

§ 7. *Conclusions and Remarks.*

1. The first conclusion from the preceding observations and experiments is, that the ancient metal instruments examined consist principally of copper, as appears: 1st, from their external and obvious properties; particularly their colour, taste, malleability, and specific gravity: 2dly, from the whole of the metals, except a small deposit, yielding nitrate of copper with nitric acid: 3dly, from the synthetic experiments.

II. I conclude that these metal instruments contain tin; which metal was made appear, by the experiments on the white deposit afforded on dissolution in nitric acid, § 5: and which also was made appear by the synthetic experiments, § 6.

III. The third conclusion is, that these metallic instruments consist of metal only, or at least of nothing else which can be detected by ordinary known modes of analysis: for they are all malleable, and uniform in their texture; which properties metals do not possess when they are mixed by fusion with extraneous substances hitherto discovered by analysis; except carbon in several metals, and siderite in iron only.

IV. The fourth conclusion is, that these ancient instruments contain none of the metals but copper and tin; for,

1. They do not contain *gold*, *silver*, or *platina*, excepting silver in the spear-head, as appears from the experiment of cupellation, § 4. (*e*).

2. They do not contain lead, for that would have oozed out in the experiments of fusion and oxidation; and would have appeared in the grain of the fractures; as well as on adding muriate of soda, and muriatic acid, to the concentrated nitrate solution, § 5. (*d*).

3. They do not contain *iron*, for that would have been shown by the prussiate of soda, § 5. (*d*); as was proved by the synthetical experiment, § 6. *Exper.* 17. (*b*).

4. They do not contain *zinc*, for that would have been shown by the blue flame and white flowers in *Exper.* § 4. (*c*) (*d*); as well as by the yellow colour of the grain of the fracture, which was shown by the synthetical experiments, § 6. *Exper.* 13. and 14.

5. *Bismuth* would have appeared on diluting the nitrate solution, § 5. (*d*).

6. *Manganese* would have been seen on concentrating by evaporation the nitrate solution, § 5. (*c*) (*d*).

7. *Arsenic* would have manifested itself by the brittleness and whiteness of the metals; by the smell and visible vapour on exposure to fire and air; and on examining the solution, § 5. (*d*), and the white deposit, § 5. (*e*).

8. *Antimony* would have produced more brittleness than these ancient metals possessed: a white vapour would have appeared on examining the white sediment with the blow-pipe, § 5. (*c*): as well as in the experiments in the assay furnace, § 4. (*b*) (*e*); and a white precipitate would have fallen on diluting the muriatic solution of the white deposit from the nitrate solution, § 5. (*e*).

9. *Cobalt* would have been detected by the prussiate of soda; and by the colour of the oxide, in the experiment in the assay furnace, § 4. (*b*); and it would have given brittleness to the ancient metal instruments.

10. It is not at all probable that *nickel* was present; but if it had been an ingredient, it most likely would have been betrayed by its greenish oxide in the experiment, § 4. (*b*).

11. *Molybdæna*, and *quicksilver* may be mentioned for the sake of order, but it is utterly unreasonable to suppose them to be present, either naturally or by art; and evident appearances, or at least traces of them, must have occurred in the preceding experiments. As for the substances called *tungsten*, *uranite*, *menackanite*, and *titanite*,* we have not yet had sufficient evidence to prove their being peculiar metals; but from the properties which have been observed to belong to them, it is quite inconsistent with the preceding experiments and obser-

* A new metal, named *Titanium*, lately announced in the German Journals.

vations to suppose them to exist in the ancient metal instruments. It will be proper also to remark, that the only species of metals known till within the last two or three centuries, were gold, silver, quicksilver, iron, copper, lead, and tin. The oxides of several of the brittle metals were known indeed to the Hebrews, Greeks, and Romans, and perhaps to several barbarous nations of great antiquity; but not one of them was used as an allay, except the oxide of zinc to compose artificial orichalcum.

It appears that the metal of the spear-head contained silver; but although the presence of it was proved by a repeated decisive experiment, § 4. (*e*), the proportion of it was too small to alter sensibly the properties of the allay of copper with tin, and could not answer any useful purpose in such a compound. I therefore believe that the silver in this instance was not purposely added; but was an accidental or natural ingredient of the copper, used for the making the metal of this spear-head. The Bishop of LLANDAFF made a few experiments on a celt, from which his lordship concludes that it seemed to contain zinc: for it emitted a blue flame, and a thick white smoke, on the first exposure of a piece to fire; but no such appearances were seen on the second exposure of the same piece to fire. Every person will readily give credit for the observations being accurately made; nor would I even refuse to admit the conclusion, that the celt examined by his lordship did contain zinc; but it is also just to observe, that a piece of copper, or of allay of copper, with tin, being exposed to fire in an open vessel, emits frequently a blue flame on a first, but not on a second exposure to fire soon after the first, § 4. (*c*); and if much air be admitted to the allay of copper with tin in fusion, a white smoke will also

sometimes be seen; as was observed in the preceding experiment, § 4. (*e*).

I suspect that the blue flame from copper when first ignited, and which ceases on fusion, is produced by the inflammation of a little of the copper already combined with oxygen; for some oxides of copper are so combustible, that if a small part of a given mass of them be ignited, the ignition will spread rapidly throughout the whole mass. Most probably celts were originally chopping tools, as we have shown in a former part of this paper, and therefore the addition of zinc to the allay of copper with tin would answer no useful purpose.

v. The fifth conclusion relates to *the proportion of the copper and the tin* to each other, in the ancient metals. I endeavoured to estimate the proportion of tin, by comparing the quantities of oxide of tin obtained from the ancient metals, with the quantities of oxide of tin obtained by the same means from allays of copper with known proportions of tin.

It appears from the analysis of the allays of copper by tin, that the oxide of tin afforded by the nitric acid solution is in the proportion of about 150 parts from every 100 parts of the metal tin, § 6. *Exper.* 1st—9th. According to this *datum* the proportion of tin in the old metals is in the following proportions, or nearly so.

1. The sauce-pan contains of tin a little more than 14 *per cent.*; that is about one part of tin and six of copper.

2. The spear-head contains 14 *per cent.* of tin; that is, somewhat less than one part of tin and six of copper.

3. The celt, No. 3; a little more than 12 *per cent.* of tin; that is, about one part of tin, and seven and a half parts of copper.

4. The lituus; nearly the same proportions of tin and copper as the celt, No. 3.

5. The scabbard; a little more than 10 *per cent.* of tin; that is, about one of tin and nine parts of copper.

6. The celt, No. 1;* a little more of tin than 9 *per cent.*; that is, about one of tin and ten parts of copper.

7. The celt, No. 2; the same proportions of tin and copper, as in the celt, No. 1.

VI. The two last conclusions are confirmed by the exact correspondence, between the ancient metals and the allays of copper by tin, in external and obvious properties, § 2. and § 6; in specific gravities, § 3. and p. 422, l. 21; and in chemical properties, § 5. and § 6. Allays of five to eighteen parts of copper with one part of tin can generally be distinguished from such allays with the addition of a very small proportion of the other metals; by the colour of their polish, the colour and texture of their grain, their strength, their hardness, their malleability, and specific gravities; without the aid of chemical analysis. It is worthy of remark, that these allays of copper with tin are evidently different, in their colour and grain, from such allays with the addition of even one-fortieth of their weight of zinc, *Exper.* 13th; and also from copper allayed by one-fortieth of its weight of zinc, *Exper.* 14th.

The similarity of the properties of the ancient metals, and of the allays of six to twelve parts of copper with one of tin, is very evident. But with smaller proportions of tin we find the allays are softer, and the grain of their fractures more open

* Mr. CAVALLO made a few experiments on a very small quantity of this celt before it came into my possession; from which he conjectured that it consisted of one part of tin, and six parts of copper.

than the ancient metals, *Exper.* 1—4.; and with larger proportions of tin we find the allays harder, more brittle, paler, and closer in texture than the ancient metals, *Exper.* 8.—11.

It is right, however, to remark, that the property of hardness of the allays of copper by tin is, *cæt. par.* as the proportion of tin, or nearly so; which is not the case with some of the ancient metals; for the spear-head and sauce-pan contain rather more tin than an equal quantity of the lituus, § 5. (*c*), which is much harder than them, § 2. (*c*); and the spear-head and sauce-pan are nearly as soft as the celts, No. 1 and No. 2, § 2. (*c*), which contain the smallest proportion of tin of any of the old metals, § 5. (*c*).

The grain also of the fractures of the spear-head and sauce-pan, before melting, is much coarser, or open, than those of the other ancient metals which contain a smaller proportion of tin, § 2. (*b*), p. 404, l. 21: but it appears from the synthetic experiments that the grain becomes finer as the proportion of tin is increased, § 6. *Exper.* 1.—12. To account for these inconsistencies I must remark, that a minute quantity of extraneous unmetallic matter may be contained in metals; so minute indeed as to elude the most rigorous analysis, or at least not to be discoverable by the ordinary modes of examination; and which also may not render the metal at all unfit for most of the uses to which it is applied. For instance, good malleable iron may contain carbon, and even phosphate of iron or siderite; and metals in general may contain a very small proportion of oxygen, and yet be as useful as the purest metals. The best English copper is accounted less tough and ductile than Swedish copper. The purest English tin crackles when it is bent or chewed, but pure Malacca tin has not this property. These

differences of properties most probably depend upon some extraneous matter; but in so small a proportion as to have hitherto eluded the research of analysis.

In the case before us, it is probable that a very minute proportion of extraneous matter was present in the spear-head and sauce-pan, especially as they were made of cast metal; which might be less hard, and less compact in texture, than an allay of pure metals containing a smaller proportion of tin to the copper, and yet the allay might be less brittle than the cast metal. This extraneous matter may be oxygen, or sulphur, or earth, although in an imperceptible quantity, introduced during the fusion. The lituus is harder, and not more brittle than the spear-head and sauce-pan; although it contains less tin. It was made of a plate of metal which had been much hammered, and must therefore either originally have been made of purer metal than the spear-head and sauce-pan, or have been rendered purer by hammering. Perhaps metals in general are rendered purer, more uniform in texture, and more dense, by remelting, than they were immediately after casting from the ore; or in the case of steel immediately after cementation; or in the case of allays after the fusion by which the union was effected. Accordingly, cast iron is rendered less brittle by repeated fusion; Mr. HUNTSMAN'S cast steel is made by merely remelting steel which had been manufactured by cementation; and Mr. MUDGE'S speculum metal, an allay of copper by tin, was not uniform and sufficiently compact till it was remelted. The specific gravity of the sauce-pan, and spear-head, was particularly increased by fusion, § 3. 2. 3; and their texture was rendered more uniform and compact, § 2.

The specific gravities of the ancient metals correspond, as

nearly as should be expected, with their composition found by analysis; and agree sufficiently with the synthetic experiments, § 3. and § 6. p. 422.

I did not find that the specific gravity of the same metal, under known circumstances alike, was so nearly the same in all cases as is stated by most writers. In the preceding experiments, different parts of the same ingot varied more than is commonly supposed in point of specific gravity.

The specific gravities of the ancient metals, after melting, varied between 8,5 and 8,8, or nearly so, § 3; and the specific gravities of the allays of three to twenty parts of copper with one of tin varied between about 8,5 and 8,9, § 6. p. 422. These great specific gravities seem surprising, because that of tin is only about 7,2, and of copper ingot about 8,420, § 6. p. 422. But of all metallic combinations that of copper with tin produces perhaps the greatest increase of density. ARISTOTLE made this observation long ago,* and the fact is familiarly known to manufacturers of bell-metal. But it does not appear that the increase of specific gravity is so great as it is stated by GLAUBER. According to him, if two balls of copper and two balls of tin of the same dimensions be melted together, the compound will afford scarcely three balls of the same dimensions as each of the four balls; and yet the three balls will weigh as much as the four balls.—" Funde prædictos globulos in unum . . . . . " iterum effunde mixturam liquefactam in typum globulorum

* Ταῦτα γαρ μίζει δε και πολύ πωῖ μόνη τὸν ὄγκον. Ὅταν δ' ἡ δύστηξις μόνη παθητικὸν, ἡ σφύξις, τὸ δὲ πάσχειν ἴφιμα, ἡ ὑδὶ πολὺ τὸ μιχθὲν εἶναι ἀμφοῖν, ἴσως συμβαίνει περὶ τὸν κασίτηρον και τὸ χαλκόν. ——————— Ὁ γαρ κασίτηρος ὡς πάθος τι ὤν, ἅπτει ὕλης τοῦ χαλκου, σχεδὸν ἀφανίζεται, και μιχθεὶς ἄπτει, χρωματίσας μόνον.—ARISTOTLE, ΠΕΡΙ ΓΕΝΕΣΕΩΣ ΚΑΙ ΦΘΟΡΑΣ ΤΟ Α. Κεφ. ι. Ὅτι ἔστι μίξις.

" primorum, et non prodibunt quatuor sed vix tres numero " globuli, pondere quatuor globulorum reservato."—GLAUBER, *de Furnis, pars* iv. p. 67. 8vo. 1651.

The specific gravity of the allays of copper by tin, and the following experiment, show that the contraction in the dimensions of these two metals on combination, cannot be so great as stated by GLAUBER.

I made two ingots of tin and two of copper, of nearly the same figure and dimensions. The specific gravity of the tin was 7,293, and that of the copper was 8,594. The absolute weight of these four ingots was 1730 grains. On combination by fusion, the compound afforded three ingots, and one-third of an ingot, of the same dimensions as the original ones; but those weighed only 1640 grains; 90 grains being wasted and adhered to the melting pot. The specific gravity of one ingot of this metallic combination was 8,340; and of another, 8,4. Consequently, after making the most reasonable allowance for the errors of the experiment, the contraction could not be one-fourth of the sum of the bulks of the metals previously to fusion, according to GLAUBER; but it might be about one-eighth.

VII. I next observe, that the proportions of tin found in the ancient metals consist with the uses for which they were made.

The principal uses of the allay of copper by tin are, to render copper less oxidable by water, or atmospheric air; to give hardness; to render it sonorous; to render it more fusible; to produce a close texture and whiteness for reflecting light; and to render copper less tough and clingy.*

Copper allayed with one of the smaller proportions of tin by manufacturers, is metal of which guns or cannon, improperly called *brass guns*, are made. Different proportions

* The workmen say, *claggy*.

of these two metals are used at different manufactories; but I believe that this gun metal seldom contains less than one part of tin to twelve of copper, nor more than one part of tin to nine of copper. Here as much strength, as is consistent with the preservation of the figure of the instrument during its use, is required: and if more tin were added, the gun would be liable to be fractured by the explosion; and if less were added, it would be liable to be bent.

Copper allayed with a somewhat larger proportion of tin than in gun metal in general, affords a metal sufficiently hard and strong for chopping tools, for many useful purposes. Of such proportions, namely, about eight or nine parts of copper and one part of tin, there is very little doubt all the ancient nations, who were acquainted with the allays of copper by tin, generally made their axes, hatchets, spades, chizzels, anvils, hammers, &c. These metals, united in these proportions, would, I believe, afford the best substitute known at this day for the instruments just mentioned, now commonly made of steel or iron. Accordingly, before the art of manufacturing malleable iron from cast iron was known at all, or at least practised extensively, that is, till within these last four or five hundred years, the allays of copper by tin must have been very generally employed. The celts may be considered as specimens of the kind of metal tools in general use before the art of manufacturing iron in the manner just mentioned was discovered: for, as hath been remarked in a former part of this paper, the celts seem to have been generally neither more nor less than metal heads of hatchets, and axes, or other chopping tools. And it is no small confirmation of this opinion, that by analysis and synthesis we have found those metals to contain, in perhaps most instances, the proportion of tin which renders them most fit for the uses to

which they were applied. This proportion being considered to be about one part of tin to nine parts of copper.

Copper allayed with a larger proportion of tin than is generally contained in celt metal; that is, with one-sixth or one-seventh of its weight of tin, is fitter for cutting instruments, and piercing, boring, and drilling tools than celt metal; because it is harder, takes a finer edge, and yet is sufficiently strong on most occasions; nor do we possess at this day any metal, that I know, which is so fit for knives, swords, daggers, spears, drills, &c. as this allay, except iron and steel.

The spear-head contains tin in the very proportion here mentioned; and if the metals had been pure, it would not have been possible, perhaps, to have made this instrument of any other metals, which were so proper, and at so small an expence.

The sauce-pan also was made of allay of copper by tin in the proportions last mentioned, § 7. p. 428; but as this instrument is sufficiently hard with less or without any tin, there seems to be no use from the addition of it. We may conjecture, indeed, that as the sauce-pan was made of cast metal, the tin was added for the purpose of rendering the copper more fusible, and thereby also for more easily casting forms of it. Perhaps also the tin was added to render the copper less readily oxidable, and for the colour of this composition.

Copper united with the proportions of tin last mentioned is very sonorous; but it is rendered much more so by still larger proportions of tin. I apprehend the sonorous property increases as the proportion of tin is increased, within certain limits; provided the allay possess sufficient strength not to be fractured by the necessary impulse. But as the brittleness increases with the increased proportion of tin, I believe not

more than one part of tin is added to three parts of copper to compose the most sonorous metal which is manufactured, namely, bell-metal.* But this allay is too brittle to be beat out into a plate for making a trumpet; and accordingly the lituus, which has been made of hammered metal, contains only about one part of tin and seven parts and a half of copper, § 7. p. 429.

Copper is united with tin for the purpose merely of becoming more fusible, and of continuing longer fluid, or cooling more slowly while passing from the melted, or fluid state, to the solid state. Such metal is used for making statues, and casts of figures in general, and is called statuary metal,† and sometimes bronze. The proportions of the two metals are various; probably according to the colour proposed, and the size and figure of the cast; as well as on account of the price of the metals.

A small proportion of zinc is sometimes added to allays of copper by tin; on some occasions, on account of colour, on others, perhaps, to render the copper still less oxidable and more fusible; and on other occasions, as I have found on inquiry, it is added from erroneous theory, or mere caprice. No one could tell me the use of zinc, which in some manufactories is added, in making gun metal.

Tin might be used also to render copper less clingy, or

* The proportion of tin varies in bell-metal from one-third to one-fifth of the weight of the copper; according to the sound required, the size of the bell, and the impulse to be given.

† The Greeks and Romans consumed vast quantities of copper in casts of figures. They added not only tin but lead to the copper. The proportions given by Pliny are one part of a mixture of equal quantities of lead and tin to fifteen parts of copper. The use of the lead I do not understand, if it was not to save expence.

more brittle, for the purpose of writing upon it, or marking it with lines and figures, as on mathematical instruments: but the allay with zinc is now preferred for these purposes, as I suppose on account of its being less hard than allays with tin, and yet sufficiently brittle; on account also of its golden colour; and also on account of its being still more difficultly oxidable by air and water.

The scabbard metal contained a rather larger proportion of tin than the celts, No. 1. and No. 2.; namely, being one-tenth of its weight, § 7. p. 429. Copper allayed by zinc would have been sufficiently hard and strong, and on other accounts preferable to the allay of copper with tin. This is, however, one proof of the extensive use of this last composition among the ancients.

The art of allaying copper with an earth-like substance; which, within a little more than these fifty years only, we have learned was an ore of a metal, namely, zinc; was known perhaps in the time of ARISTOTLE, and certainly of PLINY; for the latter informs us, that this composition *resembles oricbalcum;* and *after bis time* it was called orichalcum. Thus the *native* and *factitious* orichalcum were confounded. The ancients do not appear to have used the allay of copper by zinc, except for mere ornaments, to resemble gold. It is much more extensively employed by the moderns, and the allay of copper with tin is less extensively used: 1st, because the former is cheaper than the allay of copper with tin; 2dly, because it is now generally understood that it preserves its colour longer; 3dly, because it is easier to work it into various forms, and especially for philosophical instruments; few of which were probably made by the ancients.

The composition in common use, which contains the greatest proportion of tin, is called speculum metal. The requisites of this metal are compactness, uniformity of texture, whiteness, sufficient strength to prevent its cracking in cooling, and to bear polishing without breaking. Mr. MUDGE found the whole of these properties attainable in the greatest degree, by a little less than one part of tin with two parts of copper. But for very large instruments; such as the 40-feet telescope of Dr. HERSCHEL; the proportion of tin must be less than in small instruments, on account of the property of brittleness.

The compound of equal weights of copper and tin is so brittle, that it is not easy to conceive to what useful purpose it can be applied.

The allays of tin with copper, by which I mean those compounds of copper and tin in which the tin is in greater quantity than the copper, I believe, have not been examined. It is said, indeed, that tin allayed with a very small proportion of copper has been employed for tinning, to save much of the expence of tin; for a much thinner coat of this compound can be spread than of tin.

VIII. The next conclusion is founded on the experiments of the allays of copper with steel.

It appears that copper may be united to steel without the intermede of any other metal; for a perfectly homogeneous compound was produced by melting ten parts of copper with one of steel, § 6. *Exper.* 19. As this allay was not harder than that of copper with one-twentieth of its weight of tin, and as it did not appear that a compact and uniform malleable metal could be composed of one part of steel with two partsof copper, § 6. *Exper.* 20. I thought it unnecessary to make any

more experiments with different proportions of copper and steel. For, 1st, granting that the allays of copper by steel are as hard, strong, and malleable as those of copper by tin, it is utterly improbable that the ancients should have used steel to harden copper; on account of the great scarcity and high price of steel comparatively with tin; and also on account of the difficulty of uniting copper with steel, but facility of uniting copper with tin.

2dly. It appears that no allays of copper by steel can be made, which possess the hardness, strength, and malleability required; but which required properties we obtain by combinations of copper with tin, and with which most indubitably the ancients were well acquainted. Count CAYLUS has indeed told us, that the ancients had two methods of hardening copper; namely, by cementation, and by allaying it with iron. The first method he has not explained; nor is any method known of hardening copper without addition, except by hammering it; which it is well understood cannot produce the required hardness. As to the other method by allaying with iron, I think myself warranted in refusing the Count's single vague evidence; and in admitting the evidence of other plainly decisive experiments; which consist also with reasoning and analogy.

Philological, and antiquarian writers in giving an account of the copper arms and utensils of the ancients: as they found them much harder than copper, and that they were used for purposes to which copper would have been quite unfit; and as they saw that the ancients commonly used copper on most of those occasions in which we now use iron, or steel; were led to imagine, that in ancient times there was an art understood

of tempering copper, which had been subsequently lost.* If, instead of feigning such an hypothesis, these writers had examined by analysis the ancient implements which fell under their observation, I cannot doubt that they would have unravelled the mystery. Count CAYLUS himself had a glorious opportunity of ascertaining the composition of ancient copper instruments, when the seven swords, and hollow wheel were found at Genzac in 1751. If he had made but two adequate experiments, one to detect iron, and the other to detect tin, he would have had a much better foundation for reasoning than that of a mere hypothesis, however ingenious and learned.†

* "It appears, says Dr. LORT," in his paper upon celts, "that the ancients had "an art of tempering and hardening brass to a greater degree than is done at present, or perhaps than is necessary to be done." Archæol. Vol. V. p. 187.

With reluctance I must observe, that such an experienced inquirer as Dr. PRIESTLEY falls into the error of antiquaries, in asserting, that the ancients had a method, with which we are not well acquainted, of giving copper a considerable degree of hardness, so that a sword might be made of it with a pretty good edge. But PAUW tells us, that the Americans were in possession of the secret of giving a temper to copper equal to steel.

† At the desire of Count CAYLUS, the old metal instruments found at Genzac were examined by GEOFFROY, the younger. To prevent all suspicion of this celebrated chemist being defrauded of the honour due to him by mistaking his meaning, I shall cite his own words.

"Je cherchai à m'assurer s'il y avoit dans ces armes antiques une portion d'étain "sensible et aussi considérable que dans le métal que j'alliois. Pour cet effet je mis "dans un bain de plomb sur une coupelle un petit morceau de mon alliage, qui "aussi-tôt qu'il commença à se fondre, végéta, à cause de l'étain qu'il contenoit. J'ai "repété cette expérience, sur le métal des armes antiques, et ce métal n'ayant point vé-"gété, mais étant plus difficile à fondre que le mien, je fus convaincu que ce n'étoit "point l'étain qui durcissoit le cuivre, qui est le métal principal des armes."

This was the experiment for detecting tin; and the following is the account of the methods employed to determine the presence of iron.

There is not the least reason to suppose that the ancients added iron or steel to increase the hardness, or strength of the allay of copper by tin; nor does it appear from the experi-

" La difficulté que j'avois trouvée à fondre ce métal, me fit soupçonner qu'il conte-
" noit du fer, et mon soupçon se changea presqu'en certitude lorsque je comparai le
" grain de ce métal avec celui de quelques essais de cuivre alliés de fer, que mon père
" avoit fait dans le temps qu'il donna à l'Académie des Sciences un mémoire sur le
" tombac. Pour m'assurer s'il y avoit du fer dans ce métal j'en reduisis un petit mor-
" ceau en limaille, et la plus grande partie de cette limaille étoit attirable à l'aimant:
" mais il me restoit encore un doute sur cette preuve de l'existence du fer dans les
" armes anciennes. *Le métal dont elles sont faites étant plus dur que l'acier*, eût usé
" quelques petites parties de la lime par le frottement; ce que n'auroit point fait le
" cuivre rouge qui est beaucoup plus tendre. Ainsi pour avoir une preuve qui ne
" laissât aucun scruple, j'ai fait user à cette même meule avivée un morceau de métal
" des armes anciennes, et en lavant la boue qu'il m'a fourni pour séparer les parties
" terreuses de la meule des parties métalliques, j'ai eu une espèce de limaille extrême-
" ment fine, qui étoit attirable à l'aimant; et je ne pouvois plus craindre alors de m'être
" trompé moi-même par trop peu de défiance. Etant bien convaincu que le cuivre
" des armes anciennes étoit allié avec du fer, j'ai fait préparer plusieurs essais d'un
" métal que j'ai cru à peu près pareil, en fondant du cuivre rouge, dans lequel je faisois
" entrer du fer dans différentes proportions, et tous ces essais m'ont fourni un métal
" durci; mais si aigre qu'il étoit impossible de le forger. Cet obstacle qui m'arrêtoit
" a été bientot levé lorsque en examinant ces armes avec plus de soin, et en consultant
" à ce sujet des ouvriers connoisseurs, j'ai été assuré qu'elles étoient jettées en moule, et
" ensuite réparées à la main. J'ai cherché à imiter pour la dureté et pour le tranchant
" une épée Romaine, et je crois n'y avoir pas mal réussi dans celle que j'ai remise à
" M. le Comte de Caylus. Elle est faite avec un mêlange de cinque parties de cuivre
" rouge et d'une partie de fer fondues ensemble, puis jettées en moule."

I cannot persuade myself that it is necessary to comment upon the above passages, which Count Caylus considers as showing *decisively* that the ancient metals were hardened by iron, and not by tin. As to this learned antiquary's other method of hardening copper, which he says was employed by the ancients, it is falsified by daily experience: for it is well known that this metal is not susceptible of temper like steel, either by plunging it in any cold medium whatever, or by cementing it with salts, and carbonaceous matter. See the *Recueil d'Antiquités Egyptiennes, Etrusques, Grecques, et Romaines. Tome premier*, 4to, 1761.

ments with this mixture, *Exper.* 17, and 18, that any advantage is to be expected from this addition; at least not for cutting instruments.

I cannot confirm the opinion above delivered, that the common metal of the ancients for cutting instruments was the allay of copper with tin, by the experiments of other persons, excepting those of Mr. DIZÉ, in the *Journal de Physique* for 1790, p. 272. He had only twenty-five grains of an ancient dagger to operate upon. This small quantity, however, afforded tin and copper, as appeared on dissolution in nitric acid. But Mr. DIZÉ made several analytical experiments on eight different sorts of coins, Greek, Roman, and Gallic. It appears from these experiments that these coins contained from $\frac{5}{12}$ of a grain to $24\frac{1}{3}$ grains of tin in 100 grains of each of the old metals. And it appears that these coins contained no other metals but copper and tin.

From the preceding experiments and observations we learn that tin was infinitely more valuable to the ancients than it is to the moderns: without this metal, it is not easy to conceive how they could have carried on the practice, and invented the greater part of the useful arts. Tin was even of more importance to the ancients, than steel and iron are to the moderns; because allays of copper by tin would afford better substitutes for steel and iron, than any substitutes which the ancients, in all probability, could procure for allays of copper by tin.

We see also the importance of Britain in times more remote, probably, than those of which we have any record, or tradition; being, in all probability, the only country which furnished the metal so necessary to the progress of civilization. If Mr.

Locke had been acquainted with the properties of the allays of copper by tin, and of their extensive use in highly advanced states of civilization among the ancients; he would have known that iron was not the only metal by the use of which we are in possession of the useful arts, nor consequently is it "past "doubt, that were the use of iron lost among us, we should in a "few ages be unavoidably reduced to the wants and ignorance "of the ancient savage Americans." In the barbarous state of its inhabitants, this island was known to the civilized nations of Europe, Asia, and Africa; and denominated in two of the most ancient languages, namely, the Phœnician and Greek, by terms which denote, *the land of tin*; for such, according to Bochart, is the import of Britain, a corruption of *Barat-Anac*, or *Bratanac*; and there is no doubt of the meaning of the Greek word *Cassiterides*.

I do not mean by these observations to represent, as authors in general have done, that the ancients were not acquainted with the art of manufacturing iron, or steel, till long after the common use of copper, or that they did not know the superior properties of iron and steel; on the contrary, if this were the proper place, I could show that iron, or at least steel, was manufactured, and its useful properties understood, as early as copper was known. But steel was got anciently from those ores only which yield it in a malleable state; as it is, probably, obtained at this day in India, and called *woolz*; and as it is also obtained in the northern Circars, and likewise by the Hottentots. As steel was the only state of iron anciently manufactured, it was too scarce, and much too dear for general use; and hence the extensive use of allays of copper by tin, the best substitutes for the malleable state of iron and steel.

SECTION II. OF THE STEEL ARMS.

§ 1. *A few miscellaneous Observations.*

Of the ancient steel or iron arms and utensils in Sir JOSEPH BANKS's collection, four articles only were selected for examination.

One of these was the Steel Sword within the copper scabbard, described in Sect. I. § 1. IV. and represented by fig. 3. Tab. XI.

1. *A Sword*, fig. 1. Tab. XV. Of a number of these weapons in the collection this was the smallest. The great difference in their size and weight, it is observed, was probably intended to give every man, according to his strength and mode of fighting, an opportunity of suiting himself. The figure of the blade is particular, and seems very well contrived.

The hollow in the middle of each side does not extend more than two-thirds from the guard to the point; and terminates in a ridge, which must give great support and strength to the cutting part.

The pommel and guard had been tinned, and part of the tin coating still remains upon them. This weapon, therefore, affords a specimen of the mode of tinning iron practised by the ancients. The blade seems to have been varnished by black matter, which remains very brilliant and smooth. On one side is the inscription + BENVENUTUS +, and on the other + ME FECIT +, perfectly legible.

From the crosses, we may conclude that the maker was a Christian; and from the name, that he was an Italian. The writing is in mixed characters, but it is probable that the artist exercised his trade of a sword cutler in the northern

parts of Europe. We cannot however determine whether it be Danish, or Saxon. It was found in the river Witham, with a large quantity of other arms, in the neighbourhood of the site of Bardney abbey; and was brought up by an eel-spear, by a man who was fishing in that river, near Kirksted Wath, in 1788.

II. *An Axe.* Its form is evident from the fig. 2. Tab. XV. It was snipt a good deal, and several holes were worn in the middle, otherwise it was in a state of good preservation. It was found, with other axes, chopping instruments, and carpenters' tools, in the river Witham, in 1787, and 1788.

This axe perfectly resembles that carried by the lictors in their fasces, in basso-relievos. Its form induces one to suppose, or indeed to believe, that it was made for parade rather than use; its edge being very thin, and immediately above it the blade being thicker; but behind the thick part, exactly where the strength of an axe ought to be placed, it is thinner than in any other part. It was therefore not well calculated for chopping. The weight of this axe was one pound, and somewhat more than a quarter. Its length from eye to edge was seven inches, and the breadth was about six inches.

III. *A Dagger:* its form is represented by fig. 4. Tab. XV. It was made with great ingenuity and skill for answering the main purpose of it, that of piercing armour. It was found, together with another dagger, in Barling's Eau, near Short Ferry, in 1788.

IV. *A Sword in its Scabbard,* fig. 3. Tab. XI. I could not by any force draw it out of the scabbard. On breaking the scabbard, I found the sword destroyed by rust; but the guard, and hilt were still in a metallic state, and the pommel had

been broken off. I have already described this instrument in the account of the brass arms.

§ 2. *Chemical Properties.*

1. *The Sword*, fig. 1. Tab. XV.

(*a*) Being filed and polished, it was of the colour of steel. The blade was bent considerably before it was broken; and could not be broken without considerable force.—Comparatively with soft steel, or malleable iron, it possessed little malleability.—Under the hammer, file, and drill, it felt as hard as hardened steel. The snipt edges were hard, and strong enough to saw asunder the celts, described in this paper. Its fractured surfaces showed a silvery kind of open grain, like steel which has been hardened by plunging it, when white hot, in cold water.

The pommel and guard were much more malleable, and much less hard than the blade.

(*b*) The blade, when red hot, was malleable, but much less so than our common steel. On cooling gradually it became less hard than before; but it was not so soft as our common annealed, or distempered steel. By plunging the distempered piece of the blade, when white hot, in cold water, it was restored to its original hardness. By plunging the pommel and guard when white hot in cold water, they were rendered much harder; and by again igniting them, and letting them part with their fire gradually, they became as soft as they were originally.

(*c*) The specific gravity of the middle part of the blade, after filing off the coating, was 7,476.

(*d*) The dissolution of 300 grains of the blade in sulphuric acid and water, yielded nearly the same quantity of hydrogen

gaz as an equal quantity of our steel affords. During the dissolution the mixture became black, and a black froth appeared on its surface; and, after repose, there was a deposit of black matter. The solution, made boiling hot, was poured upon a paper filter; and being filtrated, the filter was edulcorated, by repeatedly pouring upon it pure water. The paper filter was stained black by the solution, and there was a small deposit of black matter in the apex of the cone of the filter. This black matter was carbon, in about the same proportion as our steel affords by the same treatment. The filtrated solution, on evaporation, was found to contain nothing but sulphate of iron.

(*e*) A little nitric acid being dropped upon the polished surface of the blade; and also on the pommel and guard; a black spot was produced on the parts wetted.

(*f*) The tinned part of the pommel being just wetted with nitric acid, it became white.

11. *The Axe*, fig. 2. Tab. XV. (*a*) Being polished, it appeared of almost a silvery whiteness.—It was harder than malleable iron, but was not so hard as hard steel, for it was easily filed, and bored through with the drill. It was also cut through, and the cut surface was smooth and uniform, and close, as if made of the purest metal. It bent a little, notwithstanding its form and thickness; and required a very smart stroke with a heavy hammer to break it. The grain of the fractured part was like that of close-grained steel.—It was malleable both in its cold and ignited state.—It was almost as sonorous as bell-metal.

(*b*) By quenching in cold water when ignited to whiteness, it became harder, more brittle, and open-grained; but it could not be made so hard as the sword, fig. 1. By igniting the piece so hardened, and letting it part with its fire gradually, it was rendered much less hard than it was originally.

The artist who assisted me in examining this tool, observed that it was only made of steel for about an inch from the edge; but that the rest was iron; for he conceived it to be impossible to be all steel, on account of the eye for the wooden shaft. However, on filing different parts, and cutting the instrument, no seam could be discovered, where iron had been welded to steel; and every part appeared susceptible of induration and emollition, by the usual treatment of steel to produce these changes.

(*c*) The specific gravity, before hammering, was 7,802, and after hammering the same piece, it was 7,880. After ignition to whiteness and sudden quenching, the specific gravity was 7,384.

(*d*) 300 grains of this metal dissolved in sulphuric acid and water, and afforded black matter and sulphate of iron; with the same phænomena as the dissolution of the sword, fig. 1. afforded. The black matter was carbon, in apparently the same proportion as was obtained from the dissolution of the sword, fig. 1.

(*e*) Several parts of this axe being just wetted with nitric acid, they became black spots, as is the case on so applying this acid to steel.

III. *The Dagger*, fig. 4. Tab. XV. (*a*) Being polished, it had the appearance of steel.—It was not so hard as the sword, fig. 1. but it was so very strong and tough, that it was with difficulty broken, and could be bent very considerably.—Its fractured, or rather torn surface was open-grained, and crystallized.—It was more malleable when cold, than hardened steel usually is.

(*b*) In its ignited state it was very malleable. It was susceptible of induration and emollition, by the ordinary treatment to produce these changes in steel.

(*c*) The specific gravity of this dagger was 7,413.

(*d*) The dissolution in sulphuric acid and water afforded

nothing but carbon and sulphate of iron, in about the same proportions as the dissolution of the sword, fig. 1.

(*e*) A black spot was produced by wetting this instrument with nitric acid.

IV. *The Sword*, fig. 3. Tab. XI. (*a*) The hilt being polished, it appeared like steel. It was almost as hard as common hardened steel, and as malleable.

(*b*) The hilt was very malleable in its ignited state. It was hardened, but not considerably, by quenching in cold water when white hot. It was rendered softer, after being hardened, by ignition and gradually cooling.

(*c*) The specific gravity of the hilt was 7,647: and after ignition and quenching, it was 7,427.

(*d*) The nitric acid produced black spots when applied to the polished surfaces of this metal.

(*e*) The dissolution in sulphuric acid and water afforded nothing but carbon, and sulphate of iron. The carbon was in smaller quantity from this hilt, than from the sword, fig. 1. and not more than from common steel.

§ 3. *Conclusions and Remarks.*

1. It appears that all these instruments are of steel; because they consist of carbon and iron, § 2. I. (*d*) (*e*); II. (*d*) (*e*); III. (*d*) (*e*); IV. (*d*) (*e*); because they are capable of induration by plunging them when ignited in a cold medium, § 2. I. (*b*); II. (*b*); III. (*b*); IV. (*b*); and they are softened by ignition and gradual cooling *(ibid.)*—they have the colour, texture, hardness, brittleness, § 2. I. (*a*); II. (*a*); III. (*a*); IV. (*a*); malleability when ignited, § 2. I. (*b*); II. (*a*) (*b*); III. (*b*); IV. (*b*); and specific gravity of many sorts of steel, § 2. I. (*c*); II. (*c*); III. (*c*); IV. (*c*).

2. The sword, fig. 1. appears to be the hardest, § 2. I. (*a*), and the dagger, fig. 4. the softest steel of the above instruments, § 2. III. (*a*).

3. These steel instruments appear to have been tempered, at least in the parts destined for cutting, and piercing.

4. The axe, fig. 2. being all steel, affords a proof that the ancients were not acquainted with the art of manufacturing soft malleable iron; nor consequently of welding it with steel; and that the only state of iron which they used, and could manufacture, was steel.

5. Although, it is most probable, that these steel instruments were made of steel got directly from the ore, they show that the ancients could render such steel very malleable in its ignited state, § 2. I. (*b*); II. (*a*) (*b*); III. (*b*); IV. (*b*); and free from extraneous matters, and particularly from oxygen.

6. The different degrees of hardness and brittleness of these instruments may reasonably be imputed to the different proportions of carbon which they contain; and to the different degrees of cold applied in tempering them; although the experiments, § 2. I. (*d*); II. (*d*); III. (*d*); IV. (*e*), were not made with such precision as to demonstrate the reality of these assigned causes.

7. It seems probable that the axe was tempered at a low temperature, and had been much hammered: hence its great specific gravity before hammering, § 2. II. (*c*), and the little increase of its specific gravity by further hammering; and hence the great diminution of its specific gravity by quenching in its state of ignition to whiteness, § 2. II. (*c*).

8. Iron and steel instruments are destroyed, commonly, by the oxygen of water, or oxygen of atmospherical air. The destruction of iron instruments is prevented by whatever prevents

Fig. 2.

Scale 6 Inch.

Fig. 3.

Scale

Fig. 1.

1 Foot

a

a

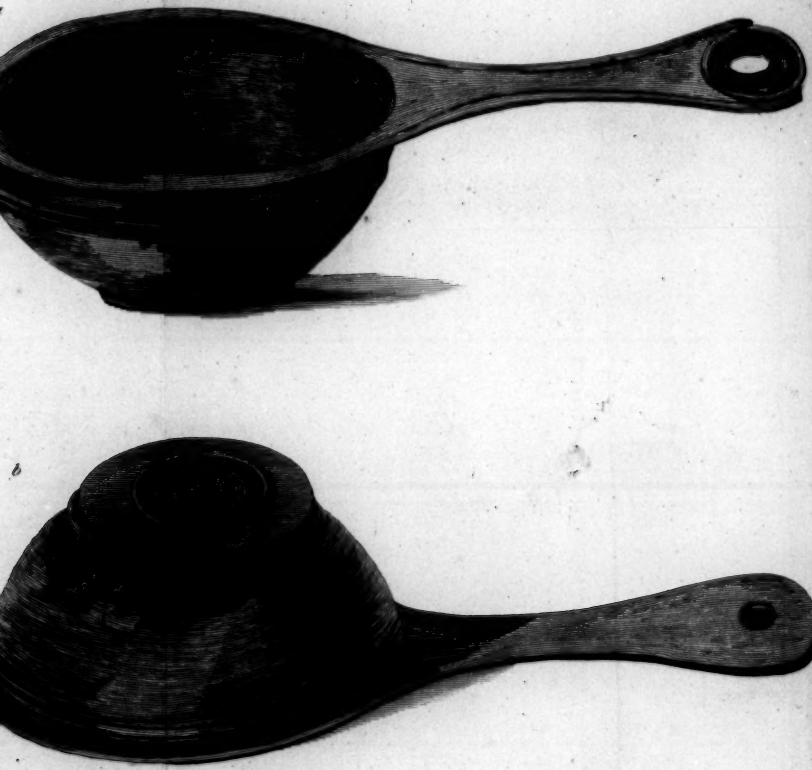
2

2 Feet

a

b

a
b



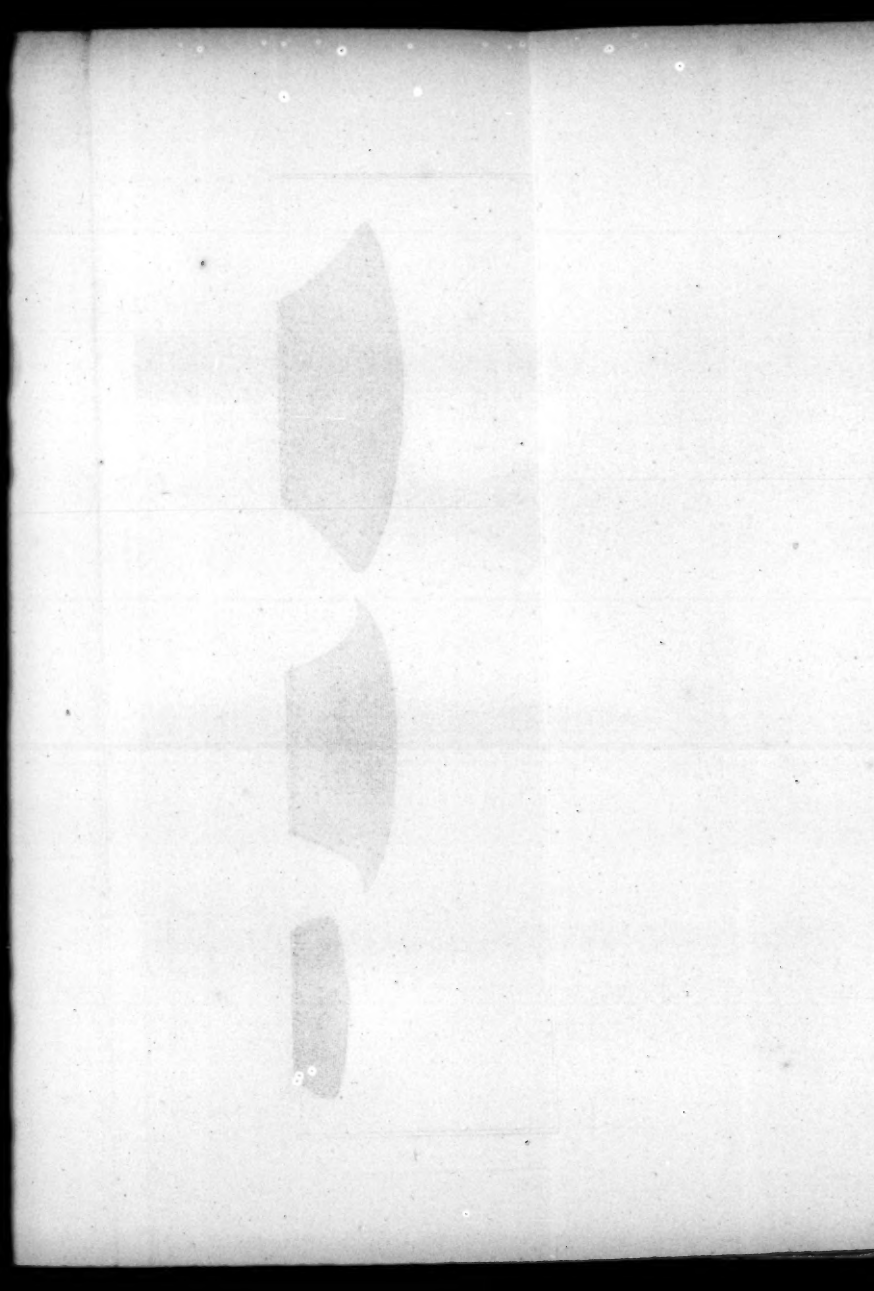


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1.

a

+BANVAHVTVS

Fig. 3.

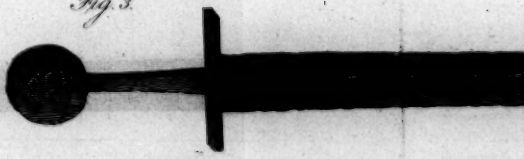


Fig. 4.

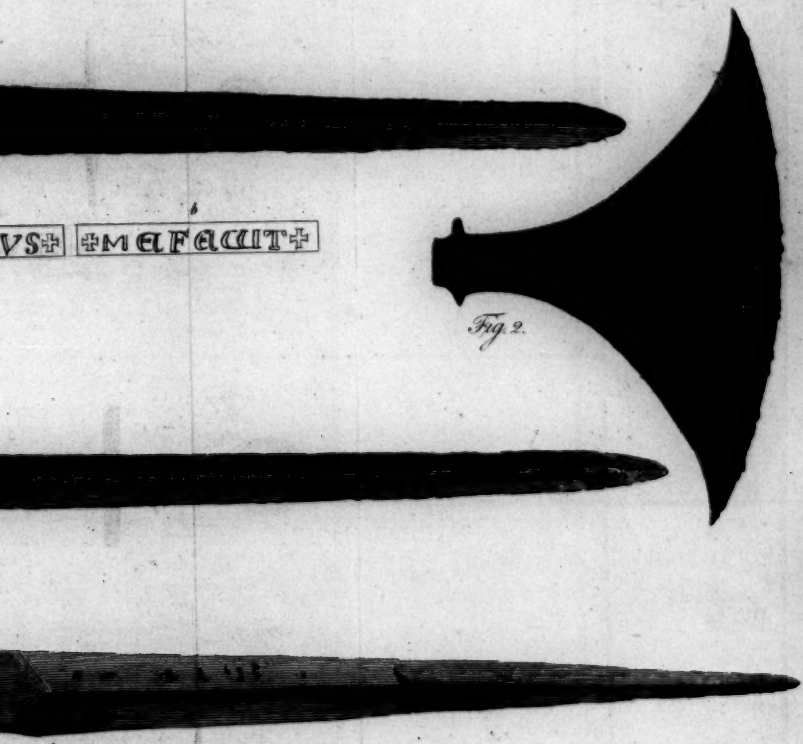


Fig. 2.

the union of the oxygen of these substances. Upon this principle the sword, fig. 1. was preserved by its varnish; but the other tools must have owed their preservation to their having been accidentally coated with earthy matter; which perhaps contained principally clay.

9. The destruction of the iron sword by oxygen within the copper scabbard; and the preservation of the part of it not in contact with the copper, is a good example of the action of copper and water united in destroying iron, the copper remaining entire, Sect. I. § 1. IV. This effect of copper upon the iron bolts and nails, in copper-bottomed ships, is a loss of the greatest magnitude.

EXPLANATION OF THE PLATES.

Tab. XI. fig. 1. Two pieces of the Lituus which had been broken.
a. The ornament of chain-work round one end of the Lituus.
Fig. 2. An ancient medal, on which the Lituus is represented.
Fig. 3. Two views of a Danish or Saxon steel Sword in its copper scabbard.
Tab. XII. *a*. The Spear-head, of the same size as the original.
b. A section of its blade, to show what proportion of it is hollow.
Tab. XIII. *a* and *b*. Two views of the Sauce-pan. The diameter of the bowl five inches, and length of the handle five inches.
Tab. XIV. fig. 1, 2, 3, the three Celts, No. 1, 2, 3.
Tab. XV. fig. 1. A steel Sword, the pommel and guard of which were tinned.
a and *b*. The writing in mixed characters on the two sides of the Sword.
Fig. 2. A steel axe.
Fig. 3. Another sword of the same kind, as fig. 1. in Sir JOSEPH BANKS's collection.
Fig. 4. A steel dagger.

XIX. *On the periodical Star α Herculis; with Remarks tending to establish the rotatory Motion of the Stars on their Axes. To which is added a Second Catalogue of the comparative Brightness of the Stars.* By William Herschel, *LL.D. F.R.S.*

Read June 9, 1796.

In my first catalogue of the comparative brightness of the stars, I announced α Herculis as a periodical star. The precision of the characters introduced in that catalogue is such, that the smallest alteration in the lustre of the stars may be discovered, by a proper attention to their expressions: the variation in the light of α Herculis is, however, pretty considerable, and cannot easily be mistaken, when strictly compared to a proper standard. The star most conveniently situated for this purpose is κ Ophiuchi; and as I have had no reason, during the time of my observations, to doubt the uniformity of its lustre, I have made use of it in the following comparisons; which seem to be sufficiently decisive, with regard to the periodical variations of the light of α Herculis.

Other stars besides κ Ophiuchi have also been consulted; but the unsteadiness of their light would draw me into difficulties, which at present it will be proper to avoid. For this reason I only give the following table, which will be found to contain at least four regular changes of the alternate increase and decay of the apparent lustre of our new periodical star, deduced from a comparison of its brightness with that of κ Ophiuchi.

In this short table, the number 64 refers to the stars in the constellation of Hercules, and 27 to those in the constellation of Ophiuchus. The characters that are used to denote their relative lustre, have been explained among the introductory remarks to the first catalogue of the comparative brightness of the stars.

Table of the Variation of Light observed in α (Fl. 64) Herculis, compared to ϰ (Fl. 27) Ophiuchi.

1795. May 18	64=27	1795. Nov. 20	64 ; 27
22	64=27	26	64 , 27
July 6	27 ; 64	28	64 ⁻ 27
August 17	27 – 64	Dec. 15	27 ; 64
18	27 – 64	1796. Jan. 9	64 ; 27
September 16	64 – 27	March 5	64 ; 27
17	64 – 27	9	64 ⁝ 27
18	64 , 27	10	64 ⁝ 27
20	64 ; 27	28	27 , 64
21	64 ⁻ 27	April 4	27 ⁻ 64
22	64 , 27	5	27 ⁻ 64
October 2	64 ; 27	9	27 ⁼ 64
6	64 ; 27	May 2	64 ⁝ 27
7	64 ; 27	4	64 ⁻ 27
9	64 . 27	5	64 ⁻ 27
11	64 ⁝ 27	10	64 =' 27
15	27 , 64	11	64 =' 27
16	27 . 64	14	64 =' 27
17	27 , 64	16	64 =' 27
25	27 ⁝ 64	17	64 =' 27
26	27 : 64	18	64 – 27
28	27 , 64	19	64 =. 27
30	27 ; 64	22	64 – 27
November 3	27 , 64	24	64 ⁻ 27
6	64 . 27	25	64 ⁻ 27
9	64 ⁝ 27	26	64 ⁻ 27
10	64 . 27	27	64 , 27

In order now from this table to obtain the time of the period, we shall first take all the successive observations from the 16th of September till the 28th of November. They shew very clearly that the star has completely gone through all its changes. For, admitting a maximum of the light of α Herculis to have been the 16th of September, we find a minimum the 25th of October; and a second maximum about the 28th of November. The period, therefore, is of somewhat more than two months duration.

But as changeable stars are subject to temporary inequalities, which will render a determination of the length of a period, from a single series of changes, liable to considerable errors, we shall now take the assistance of the most distant observations. By an inspection of the table, we find again the first maximum to have been about the 16th of September, 1795; and the fourth the 14th of May, 1796. This being an interval of 241 days, in which four successive changes have been gone through, we obtain about 60 days and a quarter for the duration of the period.

In confirmation of this computation, the table shews that our periodical star was very faint in August, 1795; bright about the middle of September; faint towards the end of October; bright the latter part of November; faint in December; bright in January, 1796; not observed in February; bright in March; faint in April; and lastly, bright again in May. This is just what should have happened according to the above determination, which, as we have seen, gives a period of eight weeks, four days and a quarter. Greater accuracy can only be obtained by future observations.

On the Rotatory Motion of the Stars on their Axes.

I shall now add a few remarks on the subject of the rotation of the fixed stars on their axes. This motion has been lately mentioned in a paper, where I could not have an opportunity to enter into the reasons why it ought to be admitted.* The discovery of the period of α Herculis furnishes me with an opportunity to say a few words upon the subject, as every addition to the list of periodical stars increases our knowledge of the construction of the celestial bodies. Not so much because now one star more is known to be subject to periodical changes in its lustre; for this would indeed be of no great consequence. But we ought not to be satisfied with merely inrolling this circumstance among the list of facts we are acquainted with. The rotatory motion of stars upon their axes is a capital feature in their resemblance to the sun. It appears to me now, that we cannot refuse to admit such a motion, and that indeed it may be as evidently proved as the diurnal motion of the earth.

Dark spots, or large portions of the surface, less luminous than the rest, turned alternately in certain directions, either towards or from us, will account for all the phænomena of periodical changes in the lustre of the stars, so satisfactorily, that we certainly need not look out for any other cause. Let us, however, take a review of any objections that might be made.

The periods in the change of the lustre of Algol, β Lyræ, δ Cephei, and η Antinoi, are short; being only 3, 5, 6, and 7 days respectively: those of o Ceti, the changeable star in

* Phil. Trans. for the year 1795, Part I. page 68.

Hydra, and that in the neck of the Swan are long, amounting to 331, 394, and 497 days. Will not a doubt arise whether the same cause can be admitted to explain indiscriminately phænomena that are so different in their duration?

To this it may be answered, that the whole force of the objection is founded upon our very limited acquaintance with the state of the heavens. Hitherto we have only had seven stars whose periodical changes have been determined. No wonder then that proper connections between their different periods were wanting. But let us now place α Herculis among the list, which is not less than 60 days in performing one return of its changes. Here we find immediately, that the step from the rotation of α Herculis to that of ο Ceti, is far less considerable than that from the period of Algol to the rotation of α Herculis; and thus a link in the chain is now supplied, which removes the objection that arose from the vacancy.

There is, however, another instance of a slow rotatory motion; and it is doubly instructive upon this occasion. In one of my former papers it has been shewn, that the 5th satellite of Saturn revolves on its axis in 79 days; this not only shews that very slow rotatory motions take place among the celestial bodies; but from the arguments that were brought to prove its rotation, which I believe no astronomer will oppose, we are led to apply the same reasoning to similar appearances among the fixed stars. A variation of light, owing to the alternate exposition of a more or less bright hemisphere of this periodical satellite, plainly indicates that the similar phænomenon of a changeable star, arises from the various lustre of the different parts of its surface, successively turned to us by its rotatory motion.

The rotations of the sun and moon, and of several of the planets, become visible in a telescope by means of the spots on their surfaces; the remote situation and smallness of the 5th satellite of Saturn, leave us without this assistance; but what we can no longer perceive, with our best optical instruments, we now supply by rational arguments. The change in the light of the satellite proves the rotation; and the rotation once admitted, proves the existence of spots, or less luminous regions on its surface, which at setting off were only hypothetical. In the same manner a still more extended similarity between the sun and the stars offers itself, by the spots that now must also be admitted to take place on their surfaces, as well as on that of the sun.

To return to the difficulty which has been started, it may be further urged, that there are some reasons to surmise that the 34 Cygni is a periodical star of 18 years return;* and that other stars seem very slowly to diminish their lustre, and may probably recover it hereafter.

In answer to this, I remark that it will not be necessary to remove objections to the rotatory motion of the stars, inferred from their very slowly changeable lustre, till they come properly supported by well ascertained facts. Many causes in the physical construction of the stars may occasion an accidental and gradual increase or decay of brightness, not subject to any regularity in its duration. But when settled periods can be ascertained, notwithstanding they should be of the most extended duration, it will not be difficult to find other causes to explain them, without giving up the rotatory motion. When the biography of the stars, if I may be allowed the expression,

* Phil. Trans. for the year 1786, Part I. page 201.

is arrived to such perfection as to present us with a complete relation of all the incidents that have happened to the most eminent of them, we may then possibly not only be still more assured of their rotatory motion, but also perceive that they have other movements, such as nutations or changes in the inclination of their axes; which, added to bodies much flattened by quick rotatory motions, or surrounded by rings like Saturn, will easily account for many new phænomena that may then offer themselves to our extended views.

Memorandum relating to the following Catalogue.

It was my intention to have continued to remark all the deviations of brightness, here assigned to the stars, from the magnitudes which are given by FLAMSTEED, either in his observations, or in the British catalogue; but I now find this author so little consistent, that it appears to be of no use to refer to his determinations. In the constellation of Aries are no less than 31 stars, in which the magnitudes of his catalogue differ from those we find in his observations; and these are generally the stars of the greatest brightness. The difference is also very considerable: thus, 41 Arietis is observed 6m, the catalogue gives 3m; 50 is observed 7m, the catalogue gives 5m; 35 is 5m, catalogue 4m; 33 is 6m, catalogue 5m; 38 is 6m, catalogue 7m.

The notes to these and the remaining constellations, therefore, will now be confined chiefly to my own observations, and to the correction of errors that have fallen under my notice.

II. *Catalogue of the comparative Brightness of the Stars.*

Lustre of the stars in Aries.			
1		7.6	Does not exist.
2		7.6	2, 8 2; 8
3		6	4, 3
4		7.6	8 – 4, 3
5	γ	4	41.5 5 – 3 Aurigæ 92 Ceti, 5 41 – 5 5 ⅓ 37 Cassiop 99 Pisc 5 –, 110 Piscium
6	β	3	6 – 4 Trianguli 88 Pegasi; 6
7		tel.	14 – 7
8	ι	6	17.8.22 2; 8 – 4
9	λ	5	9, 12 9 ⅓ 12 9, 14
10		6.7	14, 10 – 21
11		6	20, 11.16
12	κ	6.5	9, 12 9 ⅓ 12 12 – 17
13	α	2	57 Andro; 13 13, 23 Aurigæ 43 Andromedæ ⅓ 13
14		6	14, 10 9, 14 – 7
15		6	22.15 –, 18
16		8	11.16
17	π	6	17.8 12 – 17, 22
18		7	15 –, 18.23
19		6.7	20, 19
20		6	21.20, 11 20, 19
21		7	10 – 21.20
22	θ^1	6.5	8.22 17, 22.15
23	θ^2	7	18.23
24	ξ	6	31, 24 65 Ceti, 24, 64 Ceti
25		7	64 Ceti – 25
26		6.7	29, 26, 27

			Lustre of the stars in Aries.
27		6.7	26, 27
28		6	Does not exist, or is lost
29		6.7	29, 26
30		7	35, 30 – 33 16 Trianguli, 30
31		5.6	38 – 31, 24
32	ν	6	48 = 32 ϓ 34
33		5	30 – 33 35, 33 33 –, 16 Trianguli
34	μ	6	32 ϓ 34
35		4	39, 35, 33 35, 30 35 · 57
36		7	53; 36 · 50
37	o	6	43 · 37
38		7	38 – 31
39		4	39, 35
40		6	46 · 40, 45
41		3	41 · 5 41 – 5
42	π	6	42 ϓ 46 42, 43
43	σ	6	42, 43 · 37
44	ρ^1	6	54, 44
45	ρ^2	6.7	40, 45, 58
46	ρ^3	6.7	42 ϓ 46 · 40
47		6.7	63 · 47, 65
48	ε	5	58 · 48 · 63 48, 57 48 – 32
49		7	52 ϓ 49 · 51
50		7	36 · 50 · 54
51		7	49 · 51
52		6	52 ϓ 49 52, 56
53		7	45, 53; 36
54		6.7	50 · 54, 44
55		7	56 · 55
56		6.7	52, 56 · 55
57	δ	4	35 · 57 · 58 48, 57, 58

Lustre of the stars in Aries.			
58	ζ	5	57 . 58 . 48 57 , 58 , 61
59		7	62 – 59 , 60
60		7	59 , 60 . 64
61	τ^1	7	58 , 61 , 63
62		6	62 – 59
63	τ^2	6	48 . 63 61 , 63 , 65 63 . 47
64		6	60 . 64 – 66
65		7	63 , 65 47 , 65
66		7	64 – 66 7 Tauri . 66
Lustre of the stars in Canis major.			
1	ζ	3	1 . 24
2	β	2	21 , 2 , 25
3	λ	4	3 . 13 3 ; 8 Columbæ
4	ξ^1	5	4 , 5
5	ξ^2	5	4 , 5
6	ν^1	5	8 – 6
7	ν^2	5	7 , 8 7 , 23
8	ν^3	5	7 , 8 – 6
9	α	1	9 – – – all 1 m
10	$\varkappa^1$	6	13 – 10
11		5	18 . 11
12	ρ	6	17 . 12
13	$\varkappa^2$	5	3 . 13 – 10
14	θ	5	14 , 20
15	π^1	6	19 . 15 – 17
16	o^1	5	22 , 16 , 28
17	π^2	6	15 – 17 . 12
18	μ	4	20 , 18 . 11
19	π^3	6	19 . 15
20	ι	4	23 , 20 14 , 20 , 18

Lustre of the stars in Canis major.			
21	ε	3.2	21, 2 21–2
22		4	22, 16
23	γ	3	7, 23, 20
24	o^2	5.4	1. 24
25	δ	2.3	2, 25, 31
26		7	27, 26
27		7	28–27, 26
28		5	16, 28–27 28–30
29		5	30. 29
30		5	28–30. 29
31	η	3.2	25, 31 15 Navis, 31
Lustre of the stars in Canis minor.			
1		7.6	6, 1 7, 1 11, 1
2	ε	6	4, 2, 5
3	β	3	3--4
4	γ	6	3--4, 2 4. 6
5	η	6	2, 5
6	o	6	4. 6, 1 6, 11
7	δ^1	6	7, 1 7, 9
8	δ^2	6	9. 8
9	δ^3	6	7, 9. 8
10	α	1.2	19 Orionis –, 10 58 Orionis. 10 19 Orionis –, 10
11	π	6	6, 11, 1
12		5.6	Does not exist.
13	ζ	5	13 Navis, 13–14 13 Navis–13
14		6	13–14

Lustre of the stars in Cassiopea.			
1	*e*	6	3, 1--2
2		7	1--2
3		6	7.3, 1 7.3.8
4	*d*	5	5, 4-6
5	τ	5	8-5, 4 5-12 5, 14
6		6	4-6.9
7	*p*	6	7.3
8	σ	6	3.8-5
9		6	6.9.10
10		6	9.10
11	β	3.2	27, 11 27.11
12		6	5-12-13 14, 12
13		6	12-13.16
14	λ	5	17--14 33, 14 5, 14, 12
15	$\varkappa$	4	15, 33
16		6	13.16
17	ζ	4	24, 17--14 24-17
18	α	3	18; 27 18.27
19	ξ	6	19-25
20	π	6	22, 20
21		6	21; 23
22	θ	6	22, 20
23		6	21; 23
24	η	4	24, 17 24--33 24-17
25	ν	5	19-25
26	υ'	7	28; 26
27	γ	3	18; 27, 11 18.27.11
28	υ^2	6	28; 26
29		6	Does not exist.
30	μ	5	33 = τ 30
31		6	36-31, 43 46, 31

Lustre of the stars in Cassiopea.			
32		6	32 – 35
33	θ	4	24 – – 33, 14 33 = ϒ 30 15, 33
34		6	44 – 34
35		7	32 – 35
36	Ψ	5.6	36 – 31 36, 46
37	δ	3	5 Arietis ϒ 37 – – 45
38		6	42 – 38 40, 38
39	χ	6	39, 44
40	b	6	42, 40, 38
41		6	Does not exist.
42	g	6	48 – 42 – 38 42, 40
43	c	6	31, 43
44		6	39, 44 – 34
45	ε	3	37 – – 45
46	d	6	36, 46, 31
47		5	47, 49
48	e	5	50 – 48 – – 54 48 – 42
49		6	47, 49
50	f	4.5	50 – 48
51		6	Does not exist, or is lost.
52		7	53 ϒ 52 53, 52 – 55
53		7	53 ϒ 52 53, 52
54		6	48 – – 54
55		6	52 – 55
Lustre of the stars in Cetus.			
1		6	6, 1 9, 1
2	g	4.5	2, 7
3		6	17, 3, 19
4		6	4.5
5		6	4.5

Lustre of the stars in Cetus.			
6	f	5	7 – 6, 1
7	b	5	2, 7 – 6
8	i	3	8 . 31
9		6	9, 1
10		6	12 – 10, 11 12, 10 44 Piscium – 10
11		6	10, 11
12		6	13, 12 – 10 13, 12 . 15 13 – 12, 10
13		6	13, 12 20, 13, 12 13 – 12
14		6	Does not exist.
15		6	12 . 15
16	β	3	8 Pegasi ; 16 $\frac{1}{2}$ 44 Pegasi
17	ϕ^1	5	17, 19 17 . 3
18		6	23, 18
19	ϕ^2	5	17, 19 – 22 3, 19
20		6	20, 13 20 – 26
21		6	27 . 21
22	ϕ^3	5	19 – 22 . 23
23	ϕ^4	5	22 . 23, 18
24		6	Does not exist.
25		6	25 . 37
26		6	20 – 26, 33
27		6	28, 27 . 30 27 . 21
28		6	37, 28, 27
29		6	35 . 29
30		6	27 . 30, 32
31	η	3	8 . 31 . 45
32		6	30, 32 . 41 32 . 44
33		6	26, 33, 35
34		6	34 . 38
35		6	33, 35, 29
36		6	36 . 41

Lustre of the stars in Cetus.			
37		5	25 · 37, 28
38		6	34, 38 · 39
39		6	38 · 39, 40
40		6	39, 40 · 42
41		6	32 · 41 36 · 41
42		6	40 · 42 · 43
43		6	42 · 43
44		6	32 · 44
45	θ	3	31 · 45 45, 52
46		5	50, 46 48 · 46 53 – 46
47		6	47, 49
48		6	48 · 46
49		6	47, 49 · 50
50		6	49 · 50, 46
51		6	110 Piscium – 51, 98 Piscium
52	τ	3·4	45, 52 · 55
53	χ	5	55 – – 53 – 46
54		6	64, 54
55	ζ	3	52 · 55 – – 53
56	υ'	4	59 – 56, 57
57		5	56, 57 57 · 74
58		6	58, 66
59	υ²	4·5	59 – 56
60		6	60 – 61
61		7	60 – 61, 63
62		6.7	63 – 62 71 · 62
63		6	66, 63 – 62 61, 63
64		6	65 – – 64, 54 65 –, 64 24 Arietis, 64 – 25 Arietis
65	ξ'	6	65 – – 64 73 · 65 –, 64 65 – 91 65, 24 Arietis

Lustre of the stars in Cetus.			
66		6	66, 63 58, 66, 63
67		6	80, 67
68	o	3.2	68 < 10 m 68 = 13 Arietis 68 > 13 Arietis 87 Tauri > 68
69		6	69. 70
70		6	69. 70, 75
71		6	71. 62 81, 71 – 79
72	ρ	4	83. 72
73	ξ^2	5.4	87, 73. 65 73 – 91
74		6	57. 74
75		5.6	70, 75, 84
76	σ	4	89 – 76. 83
77		6	77. 80
78	ν	4.5	96, 78, 97 88, 78 – 85
79		6	71 – 79
80		6	77. 80, 67
81		6	81, 71
82	δ	3	80 – 82
83	ε	3	90, 83 76. 83. 72
84		6	75, 84
85		6	78 – 85 88 –, 85
86	γ	3	86 – 82
87	μ	4	87, 73
88		6	88, 78 88 –, 85
89	π	4.3	89, 90 89 – 76
90		8	89, 90. 83
91	λ	4	73 – 91 65 ; 91
92	α	2	92, 4 Arietis
93		6	96 – 93, 97
94		6	96, 94 – 95
95		6	94 – 95

Lustre of the stars in Cetus.			
96	χ^1	5	96, 78 96, 94 96–93
97	χ^2	4	78, 97 93. 97
Lustre of the stars in Corvus.			
1	α	4	7–1–8
2	ε	4	9, 2. 7
3		6	5–3–, 6
4	γ	3	4, 9
5	ζ	5	8–5–3
6		6	3–, 6
7	δ	3	9, 7–1 2. 7–1
8	η	5	1–8–5
9	β	3	4, 9, 7 4, 9, 2
Lustre of the stars in Eridanus.			
1	τ^4	4	11, 1–2
2	τ^5	4	1–2, 4
3	η	3	18. 3
4		6	2, 4, 6 15 ; 4
5		6	5–, 7
6		6	4, 6
7		6	5–, 7
8	ρ^4	6	10. 8
9	ρ^2	5	13–9, 10 13–9–14
10	ρ^3	4	9, 10. 8
11		3.4	16, 11, 1 16, 11. 27
12		3	19, 12
13	ζ	3	13–9
14		6	9–14
15		6	15 ; 4 15–20

Lustre of the stars in Eridanus.			
16		4	16, 11
17		4.5	17 – 22
18	ε	3.4	23, 18 – 26 23, 18. 3
19		4	27, 19, 12
20		5.6	15 – 20
21		6	22 ; 21
22		5.6	17 – 22 ; 21
23	δ	3.4	34 –, 23, 18 53, 23
24		5	32, 24 ; 25 24 – 25
25		6	24 ; 25 24 – 25
26	π	4	18 – 26, 32
27		4	11. 27, 19 27 – 33
28		6.5	36, 28
29		6.7	30, 29
30		5.6	32 – 30, 29
31		5.6	Does not exist
32		4.5	26, 32 – 30 26, 32 –, 35 32, 24
33		4.5	27 – 33. 36
34	γ	2	67, 34 –, 23
35		5	32 –, 35
36		4	33. 36, 28
37		6	40, 37
38	o	3.4	38, 40
39	A	5	40. 39. 42
40	d	5	38, 40 – 37 40. 39
41		4.3	41, 43
42	ξ	4.3	39. 42
43		5	41, 43
44		5.6	49. 44
45		5.6	45. 49
46		5	46. 47

Lustre of the stars in Eridanus.			
47		4	46 . 47 , 56
48	ν	4	48 . 57 48 –, 51
49		5 . 6	45 . 49 . 44
50	υ^1	4	50 . 52 52 , 50
51	c	4	57 –, 51 48 –, 51
52	υ^2	3	50 . 52 52 , 50
53		3 . 4	53 , 23
54		3 . 4	54 – 60
55		6	56 , 55
56		6	47 , 56 , 55 63 – 56
57	μ	4	48 . 57 –, 51
58		5 . 6	60 , 58 . 59
59		6	58 . 59
60		6	54 – 60 , 58
61	ϖ	5	69 , 61 , 65
62	b	6	65 –, 62
63		6	64 – 63 – 56
64		6	64 – 63
65	♆	5	61 , 65 –, 62
66		6	68 . 66
67	b	3	67 , 34 67 – – 68
68		6	67 – – 68 . 66
69	λ	4	69 , 61
Lustre of the stars in Gemini.			
1	H	5	18 – 1 – 139 Tauri
2		8	5 – 2 . 4
3		8	3 , 5
4		7	2 . 4 . 6
5		7	3 , 5 – 2
6		7	4 . 6

Lustre of the stars in Gemini.			
7	η	4.5	13, 7 – 31 13 : 7 –, 31
8		7.8	8 . 9
9		7	8 . 9 . 10
10		8	9, 10 . 11
11		8	10 . 11 . 12
12	.	8	11 . 12
13	μ	3	27 ⁞ 13, 7 13 . 27 13 : 7
14		7.8	16 . 14 . 15
15		7	14 . 15, 17
16		7	16 . 14
17		8	15, 17
18	ν	4	69 . 18 – 1
19		7	20, 19, 23
20		7.8	20, 23 20, 19 20 – 23
21		6.7	Does not exist.
22		7	23, 22
23		5	20, 23 19, 23, 22 20 – 23
24	γ	2.3	50 Orionis, 24, 37 Aurigæ 66 –, 24
25		7	54 Aurigæ – 25
26		5	26 . 61
27	ε	3	27 ⁞ 13 13, 27
28		6	53 Aurigæ . 28, 54 Aurigæ 36, 28
29		6.7	Does not exist.
30	ξ	6	31 – 30 . 38
31	ξ	5.4	7 – 31 – 30 7 –, 31
32		6	35, 32
33		6.7	35 . 33
34	θ	4	77, 34 – 43
35		6	38, 35, 32 35 . 33
36	d	6	36, 28 36, 37
37		6	36, 37, 39

Lustre of the stars in Gemini.			
38	*e*	6	30 . 38 − 35
39		6.7	37, 39 . 40
40		6	39 . 40
41		6	45 − 41 45, 41, 50
42	ω'	6	42 −, 44
43	ζ	3.4	34 − 43
44	ω^2	6.7	42 −, 44
45	*o*	6	51 − 45 − 41 68, 45, 41
46	τ	5	60 − 46 69, 46 62 − 46
47		6	48, 47, 52
48	*m*	6	57 − 48, 47
49		7	52 − 49 58, 49
50		6	41 . 50
51		6.5	51 − 45 51, 68
52	*n*	7.6	47, 52 − 49 52, 58
53		6.7	59 . 53
54	λ	5	54 ; 55
55	δ	3	55 . 77 54 ; 55
56	*q*	6.7	56 ; 63
57	A	5.6	57 − 48
58		7.8	52, 58, 49
59		6	64 − 59 59 . 53
60	*i*	4.5	60 − 65 60 − 46 60, 62
61	*r*	6	26 . 61 63, 61
62	*s*	5	60, 62, 46
63	*p*	6	56 ; 63, 61
64	b'	6	65 . 64 − 59
65	b^2	6	60 − 65 . 64
66	α	1	78 −, 66 −, 24 66 . 34 Aurigæ
67		7.8	68 −, 67
68	*k*	6	68 −, 67 51, 68, 45 68, 81

		Lustre of the stars in Gemini.	
69	υ	5	69 . 18 69 , 46
70		5	80 – 70
71	ο	5	71 . 80
72		6	Does not exist.
73		6.7	Does not exist.
74	*f*	6	81 , 74 – 85
75	σ	5	75 , 83
76	*c*	6	83 – 76
77	κ	4.5	55 . 77 , 34
78	β	2	78 –, 66 78 , 67 Virginis 87 Tauri – – 78
79		7	82 . 79 , 84
80	π	5	71 . 80 – 70
81	*g*	6	68 , 81 , 74
82		6	85 – 82 , 84 82 . 79
83	φ	5	83 – 76 75 , 83
84		5	82 , 84 79 , 84
85	*l*	6	74 – 85 – 82
		Lustre of the stars in Leo.	
1	κ	4	4 ; 1 1 –, 22
2	ω	5	6 – 2 ; 3
3		6	2 ; 3
4	λ	4	4 ; 1
5	ξ	4	10 , 5 – 6
6	*b*	6	5 – 6 – 2
7		6	16 – 7 , 11 8 , 7
8		6	16 , 8 , 7
9		6	13 , 9 – 12
10		5	10 , 5
11		6	7 , 11
12		7.8	9 – 12

Lustre of the stars in Leo.			
13		6	13, 9
14	o	3·4	14, 47 14, 30
15	f	6	22 . 15
16	ψ	6	16 – 7 16, 8
17	ε	8	68 – – 17 – 70 17 – 36 17 – 30 68 –, 17 –, 36 17 –, 70
18		6	18, 23
19		7	23 . 19, 21
20		6	22 –, 20
21		7	19, 21
22	g	6	22 . 15 1 –, 22 –, 20
23		6	18, 23 . 19
24	μ	3·4	47, 24
25		6·7	Does not exist.
26		7	Does not exist.
27	ν	4·5	29 – 27
28		7	Does not exist.
29	π	4	29 – 27 31 – 29
30	η	3·4	70 . 30 17 – 30 36 . 30 14 . 30
31	A	5	31 – 29 31 – 40
32	α	1	78 Geminorum –, 32, 66 Geminorum
33		6·7	Lost or 34 – – 33
34		7	42 – 34
35		6	39; 35
36	ζ	3	17 – 36 . 70 70 . 36 . 30 36 – 46 Leonis minoris 17 –, 36
37		6	37 – 42
38		6	Does not exist.
39		6	39; 35
40		6	31 – 40
41	γ	2	41, 94 41 – 94 41 –, 94

Lustre of the stars in Leo.			
42		6	37 – 42 – 34
43		6	44, 43
44		5.6	44, 45 49, 44; 43
45		6	44. 45 46, 45
46	*i*	6	46 – 47 Leonis minoris 46, 45 46 – 50 46. 51
47	*p*	4	14, 47, 24
48		6	48, 49
49		6	48, 49, 44
50		7.6	46 – 50
51	*m*	6	46. 50
52	K	6	41 Leonis minoris – 52 53, 52
53	*l*	6	53, 52
54		4.5	60. 54 –, 72
55		6.5	55 – 57 55, 62
56		6.7	59 –, 56
57		6	55 – 57 62, 57
58	*d*	6.5	63 – 58; 59
59	*c*	5	58; 59 59 –, 56
60	*b*	5	60. 54
61		5	61, 69
62	*g*	6	55, 62, 57
63	*x*	4.5	63 – 58
64		6	67 – 64
65		6	79, 65, 76
66		6	69 – 66
67		6	72 –, 67 – 64
68	*δ*	2.3	94 – 68 – – 17 68 –, 17
69		5.6	61, 69 – 66
70	*θ*	3	17 – 70 36. 70. 30 17 –, 70. 36
71		6	Does not exist.

Lustre of the stars in Leo.			
72		5	54–, 72–, 67
73	*n*	6	73 ; 81
74	Φ	4	91 . 74–, 87
75		6	84, 75, 79
76		7	79–76 65, 76
77	σ	4.5	77, 78
78	ι	4	77, 78–91
79		5.6	75, 79–76 79, 65
80		6	89–80–83
81		6	73 ; 81 86–81, 90
82		7.8	83, 82
83		8	80–83, 82
84	τ	4	84, 75
85		6	85, 88 90, 85
86		6	86–81
87	*e*	4.5	74–, 87
88		6	85, 88
89		6	89–80
90		6	81, 90, 85
91	υ	4	78–91 . 74
92		6	95, 92
93		4	93–, 95
94	β	1.2	41, 94 41–94 41–, 94–68
95	*o*	6	93–, 95, 92

Notes to Aries.

1 There is no observation of this star in FLAMSTEED's works. Perhaps one of the observations of 104 Piscium was placed 8 degrees too much north, which would produce the first Arietis.

2 There are two stars, the largest of which I take to be the 2d Arietis, and have estimated its brightess.

28 There is an observation in the second volume of the *Historia Cœlestis*, page 181; and in all appearance it is a good one. But as we find no where the 26th and 28th observed together, it is probable that only one of them existed in FLAMSTEED's time. The observation, Dec. 10, 1692, being corrected — 1′ of time in RA, will agree with the four observations on page 81, 181, 273, and 283.

Catalogue and Atlas.

1 and 28 should be out.

Atlas.

A small star under 41 towards 16 Trianguli should be out.

Notes to Canis major.

" Order of magnitude Nov. 17, 1784. ε 2m β 2.3m δ 3.2m η 3m ο 4m."

2 " Is 3m, January 9, 1796."

23 " Is hardly 5m, January 9, 1796."

Notes to Canis minor.

3 " Is 4m, January 9, 1796."

10 The comparative brightness at first sight is 10–19 Orionis; but the light of Rigel being more brilliant than that of Procyon, a continuance of its impression, when we look a good while, occasions an increase; and it becomes 19 Orionis 7 10.

12 FLAMSTEED never observed this star.

Catalogue and Atlas.

12 should be out.

Notes to Cassiopea.

"Order of magnitude May 12, 1783. $\beta\ \alpha\ \gamma\ 2''$ m δ."

8 There are two stars, nearly equal.

29 There is no observation of FLAMSTEED of this star.

41 There is no observation of this star by FLAMSTEED.

51 FLAMSTEED observed this star Dec. 16, 1691. The observation, however, is marked defective in zenith-distance. There is a star, about 9 or 10m, near the place where 51 should be.

55 That which I have estimated is the largest of several small stars about the place of 55.

Catalogue and Atlas.

29, 41, and 51 should be out.

52 and 53 are not laid down in Atlas as they are in the heavens; and on examining FLAMSTEED's observation on page 208, it appears that the catalogue is erroneous; for by that observation 52 is the most north, and 53 the most south, contrary to the catalogue.

Notes to Cetus.

14 There is no observation of this star by FLAMSTEED.

24 There is no observation of this star by FLAMSTEED.

51 Is 106 Piscium.

68 A periodical star of a great range in its lustre, as appears from the expressions I have given of its comparative brightness. Its period is 331 days, 10 hours, 19 minutes. See Phil. Trans. 1792, Part I. page 25. Different authors, however, vary a little in their determinations of the length of this period; for which we may account by admitting the star to be subject to considerable alterations in the emission of light, from some parts of its surface, which being more copious sometimes in one place, and sometimes in another at some small distance, will give a different result to the observations of the time of its maximum; while, notwithstanding, the general period of its changes will not be considerably affected by it. We have a similar instance in the rotation of Jupiter, which seems to vary on account of the little stability of its spots. See Phil. Trans. 1781, Part I. page 123 to 126.

90 Is 1 Eridani.

Catalogue and Atlas.

14 and 24 should be out.

54 " requires + 1′ 8″ of time in RA. Sept. 4. 1786."

Atlas.

18 " Is not laid down very accurately in Atlas, Sept. 22, 1795."

Notes to Corvus.

"Order of magnitude May 12, 1783. $\gamma\,\delta\,\beta\,\alpha$."

The order, by the present catalogue, does not agree with that in 1783. It is no longer $\delta\beta$, but $\beta\,\delta$; but the constellation is so low that precision is difficult.

Notes to Eridanus.

1 Is 90 Ceti.

31 FLAMSTEED has no observation of this star.

Catalogue and Atlas.

31 must be out.

40 "requires + 6′ in PD, January 31, 1786."

Notes to Gemini.

21 There is an observation by FLAMSTEED on page 294, but with a small correction, minus, in time it will agree with 20; and my double star IV. 46 marked 21 : : is 20 Geminorum.

29 There is no observation by FLAMSTEED upon this star.

54 Seems to be increasing. There is an interval of 9 months between the two observations of my catalogue. Mr. BODE supposes the star to be changeable. See *Astronomisbes Jabr-Buch*, 1788, page 255. And 1793, page 201.

72 and 73 There are no observations of these stars by FLAMSTEED.

78 "β appears to be of a deeper colour than it was a good "many years ago. I should now (Jan. 8, 1796) place it

"among the red, or ruddy stars; which formerly I did not "use to do."

Catalogue and Atlas.

21, 29, 72, and 73 should be out.

Atlas.

17 requires — 15′ in PD.

Notes to Leo.

"Order of magnitude May 12, 1783. α 1‴ m γ 2′ m β 2′ m δ ε ζ θ η μ ο ρ ν σ."

25 There is no observation of this star by FLAMSTEED; but if — 14′ 30″ in RA and + 2° 25′ 25″ in PD be applied, according to the edition of 1712, the place will then agree with 10 Sextantis. There are two very small stars near the place where 25 is put in Atlas; one of them is the star V. 63, which in my catalogue of double stars is called 25 Leonis.

26 There is an observation of this star by FLAMSTEED on page 299; but it is defective.

28 There is an observation without time on page 299, marked "*Leonis*," taken after the transit of Mars, which has probably occasioned the insertion of 28 into the British catalogue; but the observed star must have been 11 Sextantis.

38 In the observation, March 10, 1691; the number 821,66 is cast up 6 degrees too little, which produced this star; when the error is corrected, we find that the star observed was 37.

41 This is the double star in my second catalogue I. 28, and by a series of observations, it appears now that the distance between the two stars is considerably increased, since

the year 1782. I mention this circumstance here, as it will probably explain some apparent increase of brightness, that seems to have taken place in this star; for although the same quantity of light, when it is spread over more space, must appear less intense than it will do when it remains in a more confined state, it may nevertheless, by an increase of apparent magnitude, become entitled to be ranged upon a par with a brighter star.

71 FLAMSTEED never observed this star.

94 From the expressions of this catalogue, it is evident that the star is less now than it was 18 years ago.

420 of MAYER's catalogue is not visible.

Catalogue and Atlas.

25, 26, 28, 38, and 71 should be out.

WM. HERSCHEL.

Slough, near Windsor,
June 1, 1796.

XX. *Abstract of a Register of the Barometer, Thermometer, and Rain, at* Lyndon, *in* Rutland, 1795. *By* Thomas Barker, *Esq. Communicated by* Thomas White, *Esq. F. R. S.*

Read June 16, 1796.

		Barometer.			Thermometer.						Rain.
					In the House.			Abroad.			
		Highest.	Lowest.	Mean.	High.	Low.	Mean.	High.	Low.	Mean.	Lyndon.
		Inches.	Inches.	Inches.	°	°	°	°	°	°	Inches.
Jan.	Morn.	29,95	28,63	29,54	35½	25	30½	37	14	25	1,640
	Aftern.				36½	25½	31	44	20	28½	
Feb.	Morn.	30,17	28,49	13	44	28	34½	47	18	31	1,995
	Aftern.				45	29	35½	48	24½	34½	
Mar.	Morn.	29,82	28,15	30	45	33	40	47	20	30	2,101
	Aftern.				47	35	41½	54	32	43½	
Apr.	Morn.	29,71	28,80	31	50	41	45	54	36	42½	1,574
	Aftern.				54	41½	47½	62	41	51	
May	Morn.	29,99	29,18	69	64	42	52	59½	37	48½	0,404
	Aftern.				67	46½	55	74	48	60½	
June	Morn.	29,72	29,03	42	62½	50	55½	60	43	52	2,799
	Aftern.				67½	51	57	77	51	64	
July	Morn.	29,83	29,05	52	64½	55	58	62½	49	55	1,683
	Aftern.				66	56	59	82	55	65½	
Aug.	Morn.	29,82	29,13	49	68	58½	62½	69½	49	58	1,380
	Aftern.				71	59½	64½	84	60½	71	
Sep.	Morn.	29,99	29,18	63	68	56	62½	63	43	54½	0,057
	Aftern.				70½	56	65	78½	55	69	
Oct.	Morn.	29,70	28,67	17	62½	48	55	59½	39	50	4,536
	Aftern.				63½	50	56	69	48	58½	
Nov.	Morn.	30,13	28,53	37	51	36½	44	48	24½	38½	1,850
	Aftern.				52	37	45	53½	32	43½	
Dec.	Morn.	29,96	28,87	43	51	41½	46	52	33	42½	1,382
	Aftern.				51½	42	47	54	38	46½	
											21,401

THE frost which began the latter half of December, 1794, continued long in this year, an uncommonly severe winter, for a quarter of a year; yet not without a thawing day or two now and then in January, and a greater thaw for four or five days, February 8 to 12, which took away a great part of the snow, and made a greater flood than any remembered, which did more damage to the bridges all over the kingdom than was ever known, yet without taking away all the ice and snow; the frost returned again as hard as before, and with a less break near the end of February, it continued into March. It was in general a calm frost, with vast quantities of snow coming and going; so that though it was pretty thick at times, it never lay so deep as it sometimes does. But perhaps some of the deep pits of snow and beds of ice were not entirely gone at the end of March.

After the frost broke, there came near a fortnight of wet weather, not without some snow and frost; this made the spring seed time begin very late; but when it did come, it was very favourable and quick, cool but not frosty, and the grain came up well. The beginning of the summer was dry and cool; a hot week about May 20; suddenly turned cold, with frosty mornings for some days, and then mild again. The former part of the year, both in spring and summer, was remarkably cloudy, and a great deal of cold weather and frosty mornings in May and June, and perhaps some in July; yet a few hot days at times; a week of such weather with rain at the beginning of June, brought on things very much.

A showery beginning of hay time, though not in great quantities, was some hindrance to the first got hay, but it increased the quantity of the later cut, which was also better

got; and the harvest was very fine, and as sunny as the season before had been cloudy: and it continued dry, calm, sunny, and burning much till the end of September; and then at a very suitable time, the harvest being in, and still warmth enough to make the grass grow, a wet and warm October made plenty of it against winter. The season being fine, the leaves continued long upon the trees, and the winter was very open and warm, and no considerable frost at all, but mild and warm, and the ground still green; and December was warmer and freer from frost than November. But it was a remarkably stormy winter, both for frequency and violence, doing much mischief among the shipping; and almost continual south and west winds made the passage down the Channel difficult.

XXI. *Observations on the Changes which Blood undergoes, when extravasated into the urinary Bladder, and retained for some Time in that Viscus, mixed with the Urine.* By Everard Home, *Esq. F. R. S.*

Read June 16, 1796.

The greater number of cases in physic and surgery are only important and interesting to those engaged in the study of medicine; they are not connected with general science, and therefore do not properly come under the consideration of this learned Society.

Practitioners, however, in these professions have, upon many occasions, brought to light facts of importance in the animal œconomy, which could only be discovered while the human body was labouring under disease; and those have been distinguished with a place in the Philosophical Transactions.

As every change the blood undergoes must appear an object of importance to those who study the œconomy of animals, I am induced to believe the present observations on the change produced on it by being mixed with the urine, will not be considered as wholly undeserving of notice.

I was led to pay attention to this subject from considering the following case, which came under my care.

A gentleman, seventy-one years of age, in the spring 1795, found that in making water, the urine had the appearance of

blood, and congealed into a solid mass as soon as received into the vessel. This complaint appeared to have arisen from the rupture of a vessel in one of the kidneys, for he had a pain in his loins, but none in the region of the bladder. He seemed to void no water, for the whole quantity which was expelled at any one time, amounting to about 4 ounces, formed itself into a coagulum; next day he voided bloody water, which did not coagulate. This continued for three or four days, and then went entirely off.

In the spring, 1796, he had a return of the same complaint. It came on in the evening of the 3d of April; on the 4th it was very violent; and in the afternoon there was a total suppression. A catheter was passed six or seven times; but the oval holes near the end of the instrument were always filled with coagulated blood, and no urine could be drawn off. On the 5th, a larger catheter was passed, with small round holes, less likely to have the coagulum entangled in them, but no urine came away. In the evening it was introduced again, having its cavity completely lined with a flexible gum catheter, which was withdrawn as soon as the instrument was carried to the fundus of the bladder; and in this way 4 ounces of a bloody fluid were drawn off, which on exposure coagulated.

On the morning of the 6th, a pint of bloody urine was drawn off; this operation was repeated three times in the twenty-four hours, and the same quantity was brought away each time.

On the 7th, the urine drawn off was less tinged with blood; and when it was allowed to stand, the upper part became tolerably clear. There was little change in the circumstances for six days; but on the 13th the urine drawn off was of a darker red colour, and in smaller quantity. On the 16th, the

colour was more of a light brown, and after standing some time, a whitish powder was deposited; the urine drawn off in the morning upon getting up, was nearly of the natural appearance, but that brought away in the course of the day, had a deeper tinge, and more of the white sediment. It is also to be remarked, that the sediment evidently passed off only with the last part of the urine. On the 19th, the urine was tolerably clear, and the white sediment more completely separated, and in greater quantity. In the course of the night, while lying in bed, the patient voided naturally in many different attempts, 4 ounces of water, but could not make any when up. The urine now continued clear from any tinge, but no more passed without the catheter being introduced, till the 28th, when he again made some water naturally, but could not completely empty the bladder; on the 29th, the quantity which required being drawn off was less; and by the 5th of May he made water as usual, at which time the sediment began to diminish, and gradually disappeared.

From the symptoms which have been stated, it appears that part of the blood which passed into the bladder from the kidney had remained there, and formed a coagulum, which coagulum gave a bloody tinge to the urine, and caused an inability to void it without assistance, till the coagulum was dissolved.

With a view to ascertain how far this had been the case, and discover what changes the blood undergoes when placed in such circumstances, I instituted the following experiments. They were performed by Mr. CHARLES GROVER, a very ingenious surgeon, at present house surgeon in St. George's hospital.

Experiment I. Four ounces of blood were drawn from the arm into a phial containing 4 ounces of fresh urine, and the phial was kept in the temperature of the human body; in fifteen minutes the whole mixture formed an uniform firm coagulum, and appeared wholly composed of blood.

This experiment was made to ascertain the probable time the blood would take to coagulate in the bladder.

Experiment II. Six ounces of blood were drawn from the arm into 6 ounces of fresh urine; in fifteen minutes the whole mass became one solid coagulum. In seven hours, 6 drams of clear fluid were separated from it; this was poured off, and the same quantity of fresh urine was added; after standing nine hours it was poured off; some red globules were mixed with it, but sunk to the bottom undissolved. The coagulum had fresh urine added to it three times a day, the former urine being previously poured off, and allowed to stand some hours for examination.

For the first five days the coagulum appeared to undergo little change, except becoming smaller in size, and the urine poured off from it was tolerably clear, but on standing deposited a dark cloudy sediment.

On the sixth day, the urine, when poured off from the coagulum, was of a dark red colour, and deposited a greater quantity of a dark coloured sediment, but on standing became tolerably clear.

On the ninth day, the coagulum was reduced to the size of the original quantity of blood drawn from the arm.

On the 13th day, the size of the coagulum was a good deal reduced; the urine poured off from it was still more tinged with the red globules; but when allowed to stand, the upper

part became clear, and free from the red tinge, and the sediment had the appearance of a whitish powder. From this time the quantity of white sediment increased, and the size of the coagulum diminished. In its decrease from this period the loss was from its external surface, and nearly equally all round; what remained appearing like the nucleus of the original coagulum. On the twenty-fifth day, it was of the size of a large cherry, and on the twenty-ninth it entirely disappeared. Some red globules were very distinctly seen in the sediment along with the white powder.

To see how far the changes the blood had undergone in this experiment depended on the peculiar properties of the urine, the following experiment was made, with blood and common water.

Experiment III. Six ounces of blood were drawn from the arm into 6 ounces of water. In a quarter of an hour, the whole became one solid coagulum. In twelve hours, 6 ounces of a clear water, of a bright red colour, were separated, nor did it on standing deposite any sediment.

This coagulum had fresh water added to it twice a day, and what was poured off was allowed to stand for examination.

The coagulum on the second day began to break; on the fifth had a putrid smell; and in eighteen days was almost entirely dissolved.

The water which was poured off was of a bright red colour from the beginning to the end of the experiment, in consequence of the red globules being dissolved; it had a very offensive smell, but never deposited any white sediment; the coagulating lymph dissolving from putrefaction.

As it is evident, from the result of the last experiment, that

the coagulum remaining so long undissolved in the second experiment depended upon its being mixed with the urine, I was desirous of knowing whether it was the urine incorporated with the coagulum, or that which surrounded it, which produced this effect. To determine this point I instituted the following experiment.

Experiment IV. Four ounces of blood were drawn from the arm into a cup, and allowed to coagulate. 4 ounces more were drawn into a separate cup. From each of these equal portions of coagulum, at the end of three hours, 1 ounce of serum was separated, and poured off. To one of them fresh urine was added; to the other common water. The urine and water were changed night and morning.

The water was tinged of a bright red colour throughout the whole experiment, and deposited no sediment. On the eighth day the coagulum was rather looser in its texture. On the thirteenth day it began to break, and by the twentieth day it was nearly dissolved. The progress corresponding with that of the coagulum in *Experiment* III.

The urine the second day of the experiment was clear, but the bottom of the bason was covered with red globules, undissolved.

On the fifth day, the urine poured off was tinged of a bright red colour, similar to the water taken from the other coagulum; and after standing some hours a white sediment was deposited.

On the thirteenth day it was looser in texture, and more dissolved than the coagulum in the water. It continued to tinge the urine of a bright red colour, and what was poured off deposited a white sediment in greater quantity. On the

eighteenth, the coagulum was nearly dissolved; so that the coagulum immersed in the urine dissolved two days sooner than that in the water.

From this experiment we find, that it was the urine incorporated with the coagulum in *Experiment* II. that prevented the red globules from dissolving, and preserved the coagulum for so long a time, since these effects were not produced by urine while simply surrounding the coagulum.

If we compare *Experiment* II. with the result of the case, they agree so entirely, that it leaves no doubt of the process carried on in the bladder being similar to that which took place out of the body. The patient was unable to make water for twenty-four days, although the passages readily admitted, during the whole of that time, an uncommonly large instrument, which could not have been the case had there been any obstruction in them; for six days more he voided it with difficulty, but afterwards made water very well.

The coagulum out of the body was reduced in twenty-five days to the size of a cherry, and in four days more it was completely dissolved.

The patient's urine became darker, from the red globules mixing with it, in nine days. In the experiment this took place in five days.

The white sediment was first observed, in both instances, about the twelfth day; it continued to be deposited till the patient got well, and to the end of the experiment.

That the blood is capable of uniting with a quantity of urine equal to itself, so as to form a firm coagulum; that the red globules do not dissolve in a coagulum so formed; that an admixture of urine prevents the blood from becoming putrid;

and that the coagulating lymph breaks down into parts almost resembling a soft powder, are facts which I believe to be new; —they may, however, have been before ascertained, although I have not been acquainted with them.

They are certainly not generally known, and one object of the present paper is to communicate them to others.

These facts, considered abstractedly, may not appear of much importance; but when compared with what takes place in the living body, and found to agree with the process the blood undergoes in the urinary bladder, they become of no small value, since they enable us to account for the symptoms that occur in that disease, and lead to the most simple and effectual mode of relieving them.

XXII. *On the Fructification of the submersed Algæ.* By Mr. Corrêa de Serra, *F. R. S.*

Read June 16, 1796.

The light which the prevailing spirit of inquiry and observation has thrown on the means of reproduction allowed by nature to vegetable beings, is not yet equally diffused over all of them. Those whose simpler organization seems, when examined, to want some of the parts which we are accustomed to consider as essential to generation, continue to the present moment more or less involved in darkness; and their fecundation, and means of reproduction, are still objects of doubt and inquiry. Amongst them the Fuci, Ceramiums, Ulvæ, Confervæ, all submersed algæ, are perhaps in the number of the less illustrated. It is probable that their peculiar way of living, which requires from nature a particular modification in the parts destined to reproduce them, as well as in the means of performing this operation, has been the principal cause of the perplexity of naturalists on this subject. They have either sought for things in their ordinary form, which nature furnishes to these plants under a different one, adapted to their circumstances; or they have thought that she deviates from her usual ways, when she only makes use of her stubborn versatility, enforcing the execution of her general plan, by the means which at first sight seem to make her deviate from it. In the present memoir I shall

endeavour to ascertain what parts of these plants perform the sexual functions: and, in order to be clear, I will first relate in a few words, what has been observed and believed on this point, and proceed afterwards to the exposition of the opinions which observation and the strictest analogy induce me to hold on this subject.

REAUMUR was the first naturalist who bestowed a proper attention upon the fructification of the Fuci. Two elaborate memoirs of this great man are to be found, in the Parisian Transactions for the years 1711 and 1712, in which he endeavours to persuade us, that the vesiculæ filled with small grains are the female part of the fructification, in the fuci, and the filamentous hairs, which are found in different parts of the frons, the male organs. He examined eleven species of fuci, in eight of which he found grains, and only in six the filamentous hairs. It is unlucky for his opinion, that these hairs have no antheræ, and still more unlucky, that their existence has no relation at all to that of the vesicles which bear the grains, for they are persistent through all the life of the plant, without any remarkable alteration. Their situation besides is very unfit for the fecundation of the grains, except in the Fucus elongatus. Notwithstanding the weight of these objections, which he did not conceal, this otherwise sensible naturalist tried to the last to support by hypotheses, what he could not fairly prove by observations. His great name, joined to the general ascendency which the sexual system gained a little after all over Europe, gave nevertheless a common currency to his opinion; and it was received, though in a wavering manner, by LINNÆUS himself, and, what is more surprising, by the last of the JUSSIEUS. These great men indeed gave it as the prevail-

ing opinion of the day, not confirmed by any sanction of theirs. This was not the case of less profound botanists; for they, as the fashion then was, attempted to see stamina and antheræ, like the common ones, wherever they had not been observed before. I deem it unnecessary to stop a moment to consider the multitude of supposed stamina, which DONATI, GRISELINI, and others, imagined they had found in Fuci, and Ulvæ, because it is at present clearly evinced that these fancied stamina are only organs of nutrition.

Cooler observation and reflection exploded at length all these dreams; but GMELIN, and GÆRTNER, the two greater among the naturalists who followed a different way of thinking, went perhaps too far on the opposite side.

GMELIN, convinced both by reason and observation of the inutility of the REAUMURIAN antheræ, and writing at a time when the recent publications on the hydræ, and on the aphides, had made it fashionable to find examples of multiplication of organized bodies without fecundation, determined to consider these plants as in the same predicament. Every one may see, in his *Historia Fucorum*, the elaborate discussion by which he endeavours to establish his opinion. It dazzles at first sight, but, on a candid examination, all his arguments, when deprived of the apparatus of science which accompanies them, may be reduced to the following; namely, that since the supposed male organs are not such in reality, and no others are to be found, the small grains which act as seeds are prolific, without receiving external fecundation. We shall see as we proceed, how groundless is the supposition on which this argument rests.

GÆRTNER, by far a deeper naturalist than the preceding, and keeping more closely to the ways of nature, would, no

doubt, have given us the true and simple account of the fructification of the submersed algæ, if the specious ADANSONIAN theory of aphrodite plants, and his own ideas of the perfect seed, had not led him (according to my opinion) astray. The grains of the Ceramiums and Ulvæ, and the lateral internodia of the Confervæ, he excludes from the number of seeds, and believes them to be gems of a particular kind, which he calls *gongyli*, or *gemmæ carpomorphæ*, consequently not standing in need of fecundation. The grains of the fuci he judges to be true seeds; but, in this case, he believes that the uterus performs the male functions, and that the plants, in respect to their fecundation, are *aphroditæ*, having only the *apparatus fœmineus, et intimam utriusque sexus sub specie singuli copulam*. Both he and GMELIN, forced by phænomena which they could not help observing, have been in some moments very near to what I conceive to be the truth, but have sacrificed it to preconceived opinions.

In the last year two English botanists, to whom science stands indebted for many excellent descriptions and figures of fuci, Major VELLEY, and Mr. STACKHOUSE, treated this same matter, the first at large, the second occasionally. Both have stated, with great ingenuity and candour, the many objections which attend the existing systems, and both declared themselves not fully satisfied with the present state of our knowledge on this subject. Mr. STACKHOUSE, indeed, seems to cherish hopes of future discoveries of the male organs, in what he calls the concealed fibrous fructification, the antheræ not seeming necessary to him, nor the farinaceous pollen.* Perfectly agreeing with him, in what respects the needlessness of a farinaceous pollen, I cannot accede to the other parts of

* *Nereis Britannica*, in the preface, and page 30.

his opinion. A membranaceous loculament, containing the pollen, is the only necessary part of the male apparatus in plants; the filaments and the fibrous texture are only the pedicles of it, and very far from being necessary, as the sessile antheræ of numberless fructifications clearly prove. If a fibrous concealed structure could be esteemed of any use, it was already found by GMELIN, in the seed-vessels of the true fuci,* and elegantly described by Major VELLEY, in the *Fucus Vesiculosus*, and by Mr. STACKHOUSE himself, in the *Fucus Siliquosus*; but, even when magnified, it offers nothing more than simple tubular vessels, with frequent anastomoses, very remote indeed from the nature of a male apparatus.

Having stated the leading systems on the fructification of submersed algæ, I will next submit to this Society such opinions as the phænomena I have observed induce me to have about it.

All these plants are furnished with grains, which are a temporary production, and, by their falling, give rise to new individuals of the same species. In the true fuci, they are contained in an uterus, which has a temporary existence, and for their sake only, where they have a placentation, and are covered by a testa, or coat of their own. Nobody doubts that they are true seeds. The Ceramiums and Ulvæ have the same grains, as means of reproduction; and the confervæ also have them, though of a different shape. What then can be the reasons why these last are to be considered as *gongyli* and *gemmæ carpomorphæ*?

The only arguments adduced to deprive them of the nature of seeds are the three following.

1st. The grains of the Ulvæ and Ceramiums are solitary, not

* *Hist. Fucorum*, pag. 25, *et seq.*

contained in a proper uterus, consequently without a placentation. They are, says GÆRTNER, part of the medulla of their mother, and their skin is part of the maternal one.*

2d. They do not, in germinating, leave any coat behind.†

3d. In the confervæ, whose grains have some likeness to fresh internodia, two or more of them very often coalesce, but give rise to only one individual.‡

All these reasons require to be candidly discussed; and I hope the result of the investigation will afford us many additional motives to believe them to be true seeds.

The first of these objections cannot stand the test of close examination. The grains of the Ceramiums (like those of the true Fuci) fall at a proper period, which GÆRTNER calls *senium*, but which others will call maturity. If gently squeezed, they come forth from the little cavity where they are formed, and which they must leave when ripe. They come forth whole, and disengaged from the mother, and from every part of the frons; they have therefore a skin of their own. They are contained in a small uterus, proportionate to their size, which is of a temporary existence, and for them alone; where they are no doubt affixed by some placentation, from which, when they come to maturity, they are disengaged and fall. If we add to these considerations, that of their existing there enveloped in a soft juicy substance, all their difference from the seeds of the true fuci wholly disappears; § and a strong probability arises, that GÆRTNER's

* *De Fructibus*, &c. pag. xvi. *et seq.*

† Ibidem, pag. xi.

‡ Ibidem, pag. xviii.

§ I have made mention of the Ceramiums in this paper only to follow GÆRTNER through his objections. This genus, first made by DONATI, adopted by ADANSON, and GÆRTNER, has in reality scarcely any difference from the fuci.

observations were made on dry specimens, as well as with a mind not wholly impartial to his preconceived theories.

The second reason is of a more specious nature, and requires serious attention. Animals are divided into oviparous and viviparous, and a generally received comparison points out the seeds as the eggs in plants, and the gems as correspondent to living born fœtuses. We cannot conceive, says GÆRTNER, an egg where the animal, when coming forth, does not leave the shell behind; and, in the same manner, we cannot conceive a seed where the coats are not left behind in the germination. The grains of the Ulvæ, Ceramiums, &c. according to him, do not leave any coat when they germinate, and are consequently *gemmæ carpomorphæ*. Every candid naturalist will easily acknowledge, that we are not possessed of observations sufficiently decisive to enable us to speak dogmatically, on phænomena so little obvious as the germination of these grains. But I will not contest the fact, I will only examine the principle.

This general rule, of judging whether these grains be seeds or gems, by their leaving their coats in the germination, or not, is contradicted by nature, both in the instance of gems, and in that of eggs. All gems, properly so called, throw off their scaly hybernacula in the act of germinating. On the contrary, the eggs of frogs and toads leave no coat at all in their hatching, because they are possessed of none. Their very viscous albumen answers, in such an element as water, all the purposes the testa accomplishes in other eggs. Allowing GÆRTNER the exactness of his observation concerning our plants, the analogy between these submersed algæ and the aquatic oviparous quadrupeds would be striking, since both those plants and these animals are capable, from their struc-

ture, of being nourished by absorption; their embryos are hatched in the same element, and equally surrounded by a tenacious mucous substance, without any exterior coats. If the spawn of frogs be eggs, the grains of these plants must be seeds.

The third objection, very far from being an urgent one, is, I am persuaded, a capital reason to believe that the seeming lateral internodia of the Confervæ, since they are capable of cohering two or more together, and produce only one individual, are true seeds, and not gems. The coherence of two living embryos, whether gems or seeds, may form monsters, but it is equally impossible, in both cases, that perfect individuals should regularly be formed by such coalition. Observation daily shows, that of two or more neighbouring gems or seeds, one may thrive by rendering the other abortive; but, in this case, gems never cohere, the abortive one falls. In seeds, on the contrary, not only the abortive coheres to the thriving one; but this abortion happens oftener in the several species of plants, in proportion as the seeds, by their situation, are apt to cohere. In some genera it is even a regular proceeding of nature, as in the Dalea, Lagœcia, Hasselquistia, Sapindus, Ornithrophe, &c.

These objections having been I hope satisfactorily answered, I do not hesitate to consider these grains of the submersed algæ to be, what obviously they seem, their effective seeds. The figure, formation, and temporary fall of these bodies, would never have left any room for the above doubts, if their fecundation had been easily accounted for. This point we must now proceed to investigate, and examine whether the mucous

substance which surrounds these seeds can be considered as true pollen.

Pollen is by its nature immiscible with water, and specifically lighter than that fluid. In the aquatic plants, which have a farinaceous pollen, the buds of the flowers emerge from the surface of the water, and the fecundation is performed in the open air. The phænomena attending the blossom of the Potamogetones, Myriophylla, Vallisneria, &c. are too well known to require a particular mention. In some aquatic plants, whose flowers have not the faculty of emerging from water in the period of fructification, but still are endowed with farinaceous pollen, nature has taken every precaution to defend it from that element. The flower of the Zostera is situated, and its fecundation happens, in the interior cavity of the stem, which opens itself afterwards to let loose the fecundated seeds. The concave bases of the leaves in the Isoetes, closely adhering to each other, and perhaps more so in the act of fecundation, forbid the entrance of water to the minute flowers situated within them. In the Pilularia, and Marsilea, whose flowers are exposed to inundations, the fecundation is performed in perfectly closed vessels. Even in plants living in the air, nature employs numberless well known contrivances, to shelter the farinaceous pollen from the contact of water in rainy seasons.

The pollen, to be active in fecundation, needs not always be farinaceous. In most Apocyneæ it is rather a fluid; in the Orchideæ it is an aggregate of solid parts, of a ceraceous appearance; in some Contortæ it is found in a solid or rather viscous state. In the Pilularia, and Marsilea, the particles of the pollen are kept in small bags of a mucous

substance, compared by BERNARD DE JUSSIEU to dissolved gum. The original state in which it is found in every flower, before the act of fecundation, is that of a mucus, but it is perfectly active even in that state, since its particles, after becoming a little dry, if put into certain fluids, are seen, by the help of the microscope, acting in the same manner as when in the state of perfect farina.

The plants whose fructification lies unsheltered under water are very few in number; and such of them as have been hitherto thoroughly examined, (the Ceratophyllum and the Chara), have antheræ furnished with mucous pollen, not bursting in the fecundation. From the time of DILLENIUS it has been observed, that the submersed antheræ of the Ceratophyllum never burst, but are found whole, though the seeds be ripe.* If squeezed, they shed a soft and pulpous matter, like that which is found in unripe antheræ. DILLENIUS suspected that the fructification of the Chara being equally submersed, its antheræ and pollen would be of the same nature with the preceding, and observations have fully confirmed the conjectures of this great naturalist. The antheræ of the Chara do not burst in fecundation; its pollen is mucous; the germen has no pistillum, and is probably fecundated through its receptaculum, as there exists in each internodium, according to modern observations,† a chain of vessels which twist round the antheræ and the fruit, and in which a circulation of humours is visible, at least in the period of fructification.

If pollen therefore, under the shape of farina, be unfit for fecundation in the water; if nature has taken a particular care to guard this operation from the presence of that element; if

* *Plantæ Giessenses*, pag. 91. † CORTI, *Osserv. Microscop.* Lucca, 1774.

pollen can exist in an active state under a mucous appearance; and if the antheræ of perfectly submersed flowers are nothing else than closed vessels filled with mucous pollen; what doubt can we entertain, that the mucilaginous vesicles of the submersed Algæ (which contain also their seeds) are antheræ, and very appropriate to the nature and situation of these plants?

An observation made by GLEICHEN shews more clearly the propriety of such a fructification. The pollen of any flower, when put into water, in a very short time begins to move, and its particles agitate themselves in every direction, perfectly resembling the most lively animalcula. Their activity in this state lasts some time; but, if the least quantity of salt be put into the liquor, death quickly ensues, from which they never more recover.* This inclosed mucilaginous fructification was therefore the only one which could ensure existence to vegetables living chiefly in sea-water, with which their mucus is found to be immiscible.†

A still more urgent consideration will, I hope, determine those who may hesitate to consider the mucus of these plants as pollen, and the vesicles which contain it as antheræ. The parts of fructification, in all plants, are temporary, and their existence is relative to their particular functions, and to each other. The moment the fecundation happens is a moment of crisis: henceforth the fecundated parts proceed to grow and perfect themselves, the fecundating ones change and decay. This is a general law of nature, to which we know no exception, nor can any be easily conceived to exist. We must remark, that there is an epoch when the mucous substance in

* GLEICHEN *Observ. Microscop.* pag. 32. † GMELIN *Hist. Fucorum*, pag. 27.

the vesicles of the fuci suffers a material alteration, but the grains proceed to their perfection. In the *Fucus vesiculosus* this change of colour and consistency in the mucus is evident to common sight. It is still more evident in the *Fucus selaginoides*, where the temporary bright and vivid colour of the mucus, followed by a prompt decay after that period, has struck even those naturalists who most decidedly opposed the existence of male parts in these plants;* and I am confident, from the steadiness with which nature adheres to her general plans, that proper observations will demonstrate the same in every species of these submersed algæ, and confirm what the forementioned analogies induce me to think, *viz.*

That the vesicles of all these plants, whatever be their shape, if containing grains and mucus, are to be considered as hermaphrodite flowers; the grains they contain as their seeds, and the mucous substance as their pollen.

* Gærtner, pag. xxxii.

PRESENTS

RECEIVED BY THE

ROYAL SOCIETY,

From November 1795 to June 1796;

WITH THE

NAMES OF THE DONORS.

1795.	PRESENTS.	DONORS.
Nov. 5.	Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce. Vol. XIII. London, 1795. 8°	The Society for the Encouragement of Arts, Manufactures, and Commerce.
	A second Dissertation on Fever, by G. Fordyce. London, 1795. 8°	George Fordyce, M. D. F. R. S.
	Practical Observations on the Treatment of Strictures in the Urethra. London, 1795. 8°	Everard Home, Esq. F. R. S.
	A System of Divinity, in a Course of Sermons, by W. Davy. Lustleigh, Devon, 1795. 8°	The Rev. William Davy, A. B.
12.	A Description of the Jail Distemper, as it appeared amongst the Spanish Prisoners at Winchester in the year 1780, by J. C. Smyth. London, 1795. 8°	James Carmichael Smyth, M. D. F. R. S.
19.	A Meteorological Journal kept at the Reed-Lake House, from Oct. 21, 1794, to May 29, 1795. MSS. fol.	Mr. Joseph Colen.
Dec. 10.	Beiträge zur chemischen kenntniss der Mineralkörper, von M. H. Klaproth. 1 Band. Berlin, 1795. 8°	Professor Klaproth, F. R. S.
17.	Observations on Morbid Poisons, Phagedæna, and Cancer, by J. Adams. London, 1795. 8°	Mr. Joseph Adams.
24.	Nova Acta Academiæ Scientiarum Imperialis Petropolitanæ. Tomus VIII. Petropoli, 1794. 4°	The Imperial Academy of Sciences of Petersburg.
	Memoirs of the American Academy of Arts and Sciences. Vol. II. Part 1. Boston, 1793. 4°	The American Academy.

1796.	PRESENTS.	DONORS.
Jan. 21.	De Miraculis S. Coluthi et Reliquiis Actorum S. Panesniv Thebaica fragmenta, ex Museo Borgiano, illustrata opera A. A. Georgii. Romæ, 1793. 4°	John Walker, Esq. F. R. S.
	Fosilia Ægyptiaca Musei Borgiani descripsit G. Wad. Velitris, 1794. 4°	———
	Paulini a S. Bartolomæo de Veteribus Indis Dissertatio. Romæ, 1795. 4°	———
	Memoria sul Lincurio del Cav. C. A. Napione. Roma, 1795. 4°	———
	A Meteorological Journal of the Year 1795, kept in London by W. Bent. London. 8°	Mr. William Bent.
28.	Medical Commentaries for the year 1795, collected by A. Duncan. Edinburgh, 1795. 8°	Andrew Duncan, M. D.
	Dissertazione sulla trisezione dell' Angolo, ossia dell' Arco, colla piana Geometria, dell' Ab. G. M. Pizzati. Venezia, 1795. 8°	Abbate Giuseppe Pizzati.
Feb. 4.	Memoirs of the Literary and Philosophical Society of Manchester. Vol. IV. Part 2. Manchester, 1796. 8°	The Literary and Philosophical Society of Manchester.
11.	Some Account of the Collegiate Chapel of St. Stephen, Westminster, by J. Topham. fol.	The Society of Antiquaries.
	Kongl. Vetenskaps Academiens nya Handlingar, Tom. XI. för år 1790, 3d and 4th quarter; Tom. XII. för år 1791, 1st and 2d quarter; Tom. XIII. för år 1792, 3d and 4th quarter; Tom. XIV. för år 1793; Tom. XV. för år 1794; Tom. XVI. för år 1795, 1st and 2d quarter. Stockholm. 8°	The Royal Academy of Sciences of Stockholm.
	A Sermon preached at the Anniversary Meeting of the Sons of the Clergy, May 7, 1795, by C. P. Layard. London. 4°	The Rev. Charles Peter Layard, D. D. F. R. S.
18.	An Essay on the Abuse of Spirituous Liquors, by A. Fothergill. Bath, 1796. 8°	Anthony Fothergill, M. D. F. R. S.
	Experiments and Observations relative to the Influence lately discovered by M. Galvani, and commonly called Animal Electricity, by R. Fowler. Edinburgh, 1793. 8°	Richard Fowler, M. D.
	De Vi Vitali Sanguini neganda, Vira autem propria solidis quibusdam Corporis Humani Partibus adserenda, curæ iteratæ J. F. Blumenbach. Gottingæ, 1795. 4°	Professor Blumenbach, F. R. S.
	Riflessioni sopra alcuni punti di un nuovo Sistema de' Vasi Assorbenti, da F. Caldani. Padova, 1792. 8°	Sig. Floriano Caldani.
	Osservazioni sulla Membrana del Timpano, da F. Caldani. Padova, 1794. 8°	———
	Delle Fasce per uso de' Bambini. Padova, 1794. 8°	———
	Osservazioni dell Sig. F. Caldani, sopra la Trasformazione di un Insetto. 4°	———
	Lettera nella quale si esaminano alcune Riflessioni circa le nuove ricerche sulla Elettricità Animale, publicate nel Tom. XVII. degli Opusculi scelti. Padova, 1795. 8°	———

	PRESENTS.	DONORS.
	A. Knips Macoppe Aphoriami Medico-politici, edidit F. Caldanius. Venetiis, 1795. 8°	Sig. Floriano Caldani.
Feb. 25.	Institutiones Anatomicæ, auctore L. M. A. Caldani. Venetiis, 1791. Tomi II. Voll. IV. 8°	Professor Caldani, F. R. S.
March 3.	Two Prints, representing the Distribution of his Majesty's Maundy, by the Sub-Almoner, in the Chapel Royal at Whitehall	The Rev. Sir Richard Kaye, Bart. F. R. S.
10.	J. Ingen-housz Miscellanea Physico-medica. Viennæ, 1795. 8°	John Ingen-housz, M. D. F. R. S.
17.	Impartial Reflections upon the present Crisis, by H. Viscount Mountmorres. London, 1796. 8°	Viscount Mountmorres, F. R. S.
	Memoirs of the Life and Writings of the Abate Metastasio, by C. Burney. London, 1796. 3 Vols. 8°	Charles Burney, Mus. D. F. R. S.
	Memoria sobre el calculo de la Latitud del Lugar par dos Alturas de Sol, por Don D. Alcalà Galiano. Madrid, 1795. 4°	Don Dionisio Alcalà-Galiano.
April 7.	On the Prosodies of the Greek and Latin Languages. London, 1796. 8°	The Author.
14.	Seconde Continuation des Expériences, faites par le moyen de la Machine Electrique Teylerienne. Haarlem, 1795. 4°	Martinus Van Marum, M. D.
	An Account of the Experiment made on Board the Union Hospital Ship, to determine the Effect of the Nitrous Acid in destroying Contagion, by J. C. Smyth. London, 1796. 8°	James Carmichael Smyth, M. D. F. R. S.
21.	The Prevention of Poverty, by beneficial Clubs; by Edward Jones. Second Edition. London, 1796. 8°	John Lloyd, Esq. F. R. S.
	On the Composition and Properties of Water, by E. Peart. London, 1796. 8°	E. Peart, M. D.
28.	Commentariones Societatis Regiæ Scientiarum Gottingensis ad a. 1793 et 1794. Vol. XII. Gottingæ, 1796. 4°	The Royal Society of Sciences at Gottingen.
	The History of the Parishes of Whiteford and Holywell. 1796. 4°	Thomas Pennant, Esq. F. R. S.
May 5.	Anecdotes of some distinguished Persons, Vol. IV. London, 1796. 8°	William Seward, Esq. F. R. S.
12.	Astronomisches Jahrbuch für das Jahr 1798, von J. E. Bode. Berlin, 1795. 8°	Mr. J. E. Bode, F. R. S.
June 2.	Scriptores Logarithmici; or a Collection of Tracts on the Nature and Construction of Logarithms. Vol. III. London, 1796. 4°	Francis Maseres, Esq. F. R. S.
	Sammlung Astronomischer Abhandlungen, herausgegeben von J. E. Bode, 2ter Supplementband. Berlin, 1795. 8°	Mr. J. E. Bode, F. R. S.
	H. W. M. Olbers Diss. inaug. de Oculi Mutationibus internis. Gottingæ, 1780. 4°	H. W. M. Olbers, M. D.
9.	A Sermon preached upon the Occasion of the Death of the Rev. A. Kippis, D. D. by A. Rees. London, 1795. 8°	Mrs. Kippis.
	Memoria sobre las observaciones de Latitud y Longitud en el Mar. Madrid, 1796. 4°	Don Dionisio Alcalà-Galiano.

PRESENTS.	DONORS.
June 9. Dissertation sur l'Effet de la Musique dans les Maladies nerveuses, par L. Desbout. St. Petersbourg, 1784. 8°	Louis Desbout, M. D.
Dissertation Hygiénique sur la Conservation des Gens de Mer, du Dr. Bachersacht, traduite par le Dr. Desbout. St. Petersbourg, 1791. 8°	———
Mémoire sur l'Utilité d'un Traitement simple pour les Maladies Chirurgicales en général. MSS. fol.	———

INDEX

TO THE

PHILOSOPHICAL TRANSACTIONS

FOR THE YEAR 1796.

A

page

ABERNETHY, Mr. JOHN. Some particulars in the anatomy of a whale, - - - - - - 27
Acid, molybdic, experiments on, - - - - 323
Alchorne, Stanesby, Esq. Assay of the gold found in Ireland, 45
Algæ, submersed, on their fructification, - - 494
Algebra, Newton's binomial theorem demonstrated by it, - 382
Ammoniac, Sulphate of, experiments and observations on, 313
Aquarius, on the lustre of the stars in, - - 194, 212
Aquila, on the lustre of the stars in, - - 197, 215
Archimedes, remarks on his demonstrations relative to the parabolic conoid, - - - - - 96
Arcs, circular, on an elementary manner of obtaining their series, - - - - - - 142
——— on their sines, cosines, and tangents, - 153
——— on the analogy between logarithms and their trigonometrical functions, - - - - - 163
Aries, on the lustre of the stars in, - - 459, 477
Arms, &c. ancient, observations on, with experiments to determine their composition, - - - 395
——— *of copper*, historical observations on, - - 397

page

Arms, &c. of copper, external properties of, - - 403
——— specific gravities of, - - - 407
——— experiments on, with fire, - - 408
——— with nitric acid, - 411
——— synthetical observations and experiments on, 414
——— conclusions and remarks on, - - 424
——— *of steel*, observations on, - - - 444
——— chemical properties of, - - 446
——— conclusions and remarks on, - - 449
ATWOOD, GEORGE, Esq. The construction and analysis of geometrical propositions, determining the positions assumed by homogeneal bodies which float freely, and at rest, on a fluid's surface; also determining the stability of ships, and of other floating bodies, - - - - 46
Axe, ancient, account of one, - - - 445, 447

B

Balls of stone, found in the works of the Huddersfield canal, 350
Bark, Peruvian, annual consumption of, in this country, - 283
BARKER, THOMAS, Esq. Abstract of a register of the barometer, thermometer, and rain, at Lyndon, in Rutland, 1795, - 483
Barometer, register of, at Lyndon, in Rutland, - - 483
BENNET, The Rev. ABRAHAM. Account of an earthquake felt in Derbyshire, - - - - 360
Bingley, Mr. Assay of some ancient metals, - - 410
Birds, remarks on their eyes, - - - 11
Blood, on the changes it undergoes in the urinary bladder, - 486
——— experiments upon it, - - - - 489
Blue shadows, remarks on, - - - 255
BROUGHAM, HENRY, Jun. Esq. Experiments and observations on the inflection, reflection, and colours of light, - - 227

C

Canis major, on the lustre of the stars in, - - 461, 477
——— *minor*, on the lustre of the stars in, - - 462, 477
Capricornus, on the lustre of the stars in, - - 199, 217
Cassiopea, on the lustre of the stars in, - - 463, 478
Celts, observations on, - - - - - 402
Ceramiums, on their fructification, - - - 494
Cetus, on the lustre of the stars in, - - - 464, 479
Chapman, remarks on his method of approximating to the areas of curves, - - - - - 114

page

Cobalt, remarks on a solution of it in muriatic or nitro-muriatic acid, - - - - - - 333
Cold, on its influence upon the health of the inhabitants of London, - - - - - - - - 279
Colours of flame, remarks on, - - - - - 254
——— *of light*, experiments and observations on, - 227
——— *rings of*, from a concave glass mirror, remarks on, - 260
Comet, account of the discovery of one, - - - 131
——— additional observations on, - - - 133
Conferva, on their fructification, - - - - 494
Copper, on allaying it with iron, - - - 419, 438
——————— with tin, - - - - 414, 433
——————— with zinc, - - - 418, 437
Corrêa de Serra, Mr. On the fructification of the submersed algæ, - - - - - - - 494
Corvus, on the lustre of the stars in, - - 468, 480
Cosines of circular arcs, remarks on, - - - 153
Curves, on approximating to their areas, - - 114
Cygnus, on the lustre of the stars in, - - - 201, 217

D

Dagger, ancient, account of one, - - - 445
Deaths, tables of, in the beginning of the years 1795 and 1796, 282
Delphinus, on the lustre of the stars in, - - 204, 220
Driffield, Mr. Christopher. Account of an earthquake felt in Lincolnshire, - - - - 355

E

Earthquake felt in various parts of England, account of, - 353
——— account of it from Derbyshire, - - 358
——————— from Leicestershire, - - 355
——————— from Lincolnshire, - - 355
——————— from Nottinghamshire, - - 362
——————— from Warwickshire, - - 356
——————— from Worcestershire, - - 358
——— observations upon it, - - - 372
Electricity, reasons against its being the cause of earthquakes, - 377
Emerson, Mr. Improvement of his computation of the hyperbolic logarithm of 10, - - - - 140
Equuleus, on the lustre of the stars in, - - 204, 220
Eridanus, on the lustre of the stars in, - - 468, 480

page

Eye, human, experiments on, - - - - 3, 6
Eyes of birds, remarks on, - - - - - 11
—— *of fishes*, remarks on, - - - - - 21
—— *of quadrupeds*, remarks on, - - - - 10

F

Fishes, remarks on their eyes, - - - - 21
Flame, on the different colours of it, - - - 254
Floating bodies, propositions determining their positions, - - 46
Fluids, on the resistance of bodies moving in them, - - 128
Fringes, coloured, remarks on those which surround the shadows of bodies, - - - - - 256
Fuci, on their fructification, - - - - 494

G

Gas, inflammable, remarks on its probable agency in earthquakes, 380
Gemini, on the lustre of the stars in, - - 470, 480
Glands, lymphatic, remarks on, - - - 31
Gold, native, discovered in Ireland, account of, - - 34, 38
—— specific gravity of, - - - 43, 45
—— assay of, - - - - - 43, 45
GRAY, EDWARD WHITAKER, M. D. Account of the earthquake felt in various parts of England, November 18, 1795; with some observations thereon, - - - 353
GREGORY, The Rev. EDWARD. Account of an earthquake felt in Nottinghamshire, - - - 362
Gun-metal, remarks on, - - - - 418, 433

H

HATCHETT, CHARLES, Esq. An analysis of the Carinthian Molybdate of lead; with experiments on the molybdic acid. To which are added some experiments and observations on the decomposition of the sulphate of ammoniac, - - 285
HEBERDEN, WILLIAM, Jun. M. D. Of the influence of cold upon the health of the inhabitants of London, - - 279
HELLINS, The Rev. JOHN. Mr. Jones's computation of the hyperbolic logarithm of 10 improved: being a transformation of the series which he used in that computation to others which converge by the powers of 80. To which is added a postscript, containing an improvement of Mr. Emerson's computation of the same logarithm, - - - - 135
Hercules, on the lustre of the stars in, - - 205, 221

page

Herculis, α, observations on, - - - 452

HERSCHEL, MISS CAROLINE. Account of the discovery of a new comet, - - - - 131

HERSCHEL, WILLIAM, LL.D. Additional observations on the comet, - - - - - 133

——— on the method of observing the changes that happen to the fixed stars; with some remarks on the stability of the light of our sun. To which is added, a catalogue of comparative brightness, for ascertaining the permanency of the lustre of stars, - - - 166

——— On the periodical star α Herculis; with remarks tending to establish the rotatory motion of the stars on their axes. To which is added a second catalogue of the comparative brightness of the stars, - - 452

HOME, EVERARD, Esq. The Croonian lecture on muscular motion, - - - - - - 1

——— A description of the anatomy of the sea otter, from a dissection made November 15, 1795, - 385

——— Observations on the changes which blood undergoes, when extravasated into the urinary bladder, and retained for some time in that viscus, mixed with the urine, 486

Huddersfield canal, account of some balls of stone, found in its works. - - - - - 350

I

Images, on their formation by reflection, - - 268

Instruments, ancient. See *Arms.*

JOHNSON, ROBERT AUGUSTUS, Esq. Account of an earthquake felt in Warwickshire, - - - - 356

JOHNSTONE, Dr. Account of an earthquake felt in Worcestershire, - - - - - 358

Jones, Mr. his computation of the hyperbolic logarithm of 10 improved, - - - - - 135

Ireland. Account of the native gold found there, - 34, 38

K

KING, Mr. WILLIAM. Account of an earthquake felt in Leicestershire, - - - - - 355

Kirwan, Richard, Esq. Specific gravity of the gold found in Ireland, - - - - - 45

Klaproth, Mr. Account of some experiments made by him, 286

L

Lead, Carinthian Molybdate of. See *Molybdate.*

page

Lecture, Croonian, on muscular motion, - - - 1
Leo, on the lustre of the stars in, - - - 473, 481
L'Huilier, M. Simon. Manière élémentaire d'obtenir les suites par lesquelles s'expriment les quantités exponentielles et les fonctions trigonométriques des arcs circulaires, - - 142
Light, on the inflection, reflection, and colours of it, - 227
—— on its flexion, - - - - - 228
—— on its reflection, - - - - - 235
—— *of the sun*, remarks on its stability, - - - 285
Lituus. Account of one, - - - - - 397
Lloyd, John, Esq. An account of the late discovery of native gold in Ireland, - - - - - 34
Logarithm, hyperbolic, of 10, Mr. Jones's computation of it improved, - - - - - 135
—— Mr. Emerson's computation of it improved, - - - - - 140
Logarithms, remarks on, - - - - - 145
—— on the analogy between them and the functions of circular arcs, - - - - - 163

M

Macdonald, John, Esq. Observations of the diurnal variation of the magnetic needle at Fort Marlborough, in the island of Sumatra, - - - - - 340
Menzies, Mr. Archibald. A description of the anatomy of the sea otter, from a dissection made November 15, 1795, 385
Mills, Abraham, Esq. A mineralogical account of the native gold lately discovered in Ireland, - - - 38
Milnes, Mr. William. Account of an earthquake felt in Derbyshire, - - - - - 358
Mirrors, convex, experiments with, - - - - 2
Molesworth, William, Esq. Specific gravity of the gold found in Ireland, - - - - - 44
Molybdate of lead, Carinthian, analysis of, - - 285, 320
—— characters of, - - - - 292
—— experiments on, with water, - - - 293
—— with fixed alkalies, - 287, 294
—— with sulphur, - - 296
—— with carbonate of ammoniac, 296
—— with muriate of ammoniac, - 287
—— with black flux, - 301
—— with nitric acid, - 287
—— with muriatic acid, - 303

page

Molybdate of lead, experiments on, with sulphuric acid, - 308
——— general observations on, - - 329
Motion, muscular, Croonian lecture on, - - - - 1
——— *rotatory*, of the stars, remarks on, - - 455

N

Needle, magnetic, observations of the diurnal variation of, in Sumatra, - - - - - - 340
Newton, his binomial theorem demonstrated by algebra, - 382

O

Otter, sea, anatomy of, - - - - 385
OUTRAM, Mr. BENJAMIN. Particulars of the discovery of some very singular balls of stone, found in the works of the Huddersfield canal, - - - - 350

P

PEARSON, GEORGE, M. D. Observations on some ancient metallic arms and utensils; with experiments to determine their composition, - - - - - 395
Pegasus, on the lustre of the stars in, - - - 208, 224
Plants, aquatic, remarks on their fecundation, - - 502
Pollen, remarks on, - - - - 502
Presents, received by the Royal Society, from November 1795 to June 1796, - - - - - 507

Q

Quadrupeds, remarks on their eyes, - - - 10

R

Rain, register of, at Lyndon, in Rutland, - - 483
Ramsden, Mr. Experiments made by him, - - 2
Resistance of bodies which move in fluids, remarks on, - 128
Rings of colours from a concave glass mirror, remarks on, - 260

S

Sagitta, on the lustre of the stars in, - - - 211, 226
Saucepan, ancient, account of one, - - - 400
SEWELL, The Rev. WILLIAM. Newton's binomial theorem legally demonstrated by algebra, - - - 382

page

Shadows, blue, remarks on, - - - - 255
Ship, account of one which wanted stability, - - 117
Ships, propositions determining their stability, - - 46
Sines of circular arcs, remarks on, - - - 153
Spear-head, ancient, account of one, - - - 399
Stars, fixed, on the method of observing their changes, - 166
—— catalogue of their comparative brightness, - 187, 458
—— on the lustre of those in Aquarius, - - 194, 212
—— in Aquila, - - - 197, 215
—— in Aries, - - 459, 477
—— in Canis major, - - 461, 477
—— in Canis minor, - - 462, 477
—— in Capricornus, - - 199, 217
—— in Cassiopea, - - 463, 478
—— in Cetus, - - 464, 479
—— in Corvus, - - 468, 480
—— in Cygnus, - - 201, 217
—— in Delphinus, - - 204, 220
—— in Equuleus, - - 204, 220
—— in Eridanus, - - 468, 480
—— in Gemini, - - 470, 480
—— in Hercules, - - 205, 221
—— in Leo, - - 473, 481
—— in Pegasus, - - 208, 224
—— in Sagitta, - - 211, 226
—— on their rotatory motion, - - - 455
Stirling, remarks on his method of approximating to the areas of curves, - - - - - 114
Stone, balls of, found in the works of the Huddersfield canal, 350
STORER, Dr. Account of an earthquake felt in Nottinghamshire, 368
Streaks produced by looking at a luminous body, remarks on, - 267
Sulphate of ammoniac, on its decomposition, - - 313
Sumatra, on the variation of the magnetic needle in that island, 340
Sun, remarks on the stability of its light, - - - 185
Sword, ancient, account of one, - - 444, 445

T

Tangents of circular arcs, remarks on, - - - 153
Theorem, binomial, demonstrated by algebra, - - - 382
Thermometer, register of, at Lyndon, in Rutland, - - 483
—— in Sumatra, - - - 346

page

V

Variation of the magnetic needle in Sumatra, observations of 340
Ulvæ, on their fructification, - - - - 494
Utensils, ancient. See *Arms.*

W

Weather of 1795, remarks on, - - - 484
——— at Sumatra, register of, - - - 346
Whale, some particulars in its anatomy, - - - - 27

From the Press of
W. BULMER & Co.
Cleveland-Row, St. James's.

ERRATA.

PART I.

P. 143, l. 3, *for* affraiant, *read* effraiant.

Note from HENRY BROUGHAM, Jun. Esq. author of the paper on the inflection, reflection, and colours of light. See page 227, &c.

" Owing to an error which crept into the integral calculus by which the problems on " the trajectory of light were resolved, two of these solutions are erroneous, and must be " corrected thus: 1. When the bending force is inversely as the distance, the curves to be " squared are, a conic hyperbola, and a logarithmic, $y^2 = \frac{1}{l\frac{x}{a}}$. The trajectory, there- " fore, cannot be found in finite terms; its equation is $y^2\, l\frac{a}{x} = x^2$; and the sub- " tangent is to the subnormal as 1 to $l\frac{a}{x}$. 2. When the bending force is inversely as " the square of the distance, the curves to be squared are a cubic hyperbola, $y = \frac{1}{x^2}$, " and a cubic conchoid, $y^2 = \frac{x^3}{a-x}$; therefore the equation to the trajectory is " $(a-x)\, y^2 = x\, x^2$, which belongs to a *cycloid*, the radius of whose generating circle is " a. In general, if the force be inversely as the mth power of the distance, the equation " of the trajectory will be $(a^{m-1} - x^{m-1})\, y^2 = x^{m-1}\, x^2$, which agrees also with the " first case, where m being $= 1$, $\underline{a^{m-1}}$, may be esteemed the hyperbolic logarithm " of a."

H. BROUGHAM.

Edinburgh,
July 2, 1796.